

Camp Verde Wastewater Treatment Plant Repair

Camp Verde, Arizona

Submitted by Truesdell Corporation



Extensive visible cracking in concrete walls

A newly constructed wastewater treatment facility in Camp Verde, AZ, was under-designed, as large cracks formed on two of the concrete walls during its initial water test prior to backfilling. The 128 x 92.5 ft (39 x 28.1 m) water treatment tank is a reinforced concrete wall and slab system comprising 10 individual cells that perform specific treatment tasks. The walls are 18 ft (5.4 m) tall and some reach an unsupported length of over 90 ft (27.4 m). The large spans result in high bending forces that must be developed without allowing cracking.

Evaluations of the structure determined that filling the tank would overload the structural walls due to insufficient horizontal reinforcement at the wall intersections, a design flaw based on an inaccurate assumption regarding all cells being continuously full and the structure fully backfilled. A repair method using reinforced concrete bolsters at all intersecting walls and at the wall-to-slab connections was considered, but it was extremely costly and would have resulted in a substantial reduction to the tank's capacity.

As a result, a new design-build team was used and tasked with developing an alternate strengthening solution that considered the strength requirements

associated with various deficiencies, load conditions, and future operations, while maintaining the desired volume capacity of the tank, with minimal impact to the construction schedule.

ENGINEERING ANALYSIS

As-built drawings of the original construction were used to create a finite element model of the concrete tank system. Analysis involved the use of 41 distinct load cases that included the pressure of the backfill and varying combinations of load cases resulting from filling individual and combinations of cells with water. Each of the 41 load cases was evaluated at each intersecting wall location to determine the worst case load conditions for negative moment and direct tension. Each individual finite element was evaluated to provide for specific load demands along the wall heights and lengths to minimize the length of each repair and the associated project costs. This curtailing of the carbon fiber-reinforced polymer (CFRP) created installation and layout complexities; however, it led to substantial cost savings.

STRENGTHENING SOLUTION

A combination of technologies provided the solution, including the use of a unidirectional carbon fiber-reinforcing system, high-strength steel plates and bolts, and reinforced concrete and epoxy dowelling with steel reinforcing. A CFRP system was selected as part of the strengthening solution.

To provide an optimal solution and remain as cost effective as possible, detailed layups were determined at each intersecting wall location. The laminate thickness and length were curtailed down the wall and away from the wall intersections, in direct proportion to load demands as determined by the finite element analysis.

Anchorage of the CFRP and the transfer of the tensile force through the intersecting walls was accomplished using steel plates and through bolts. Each steel angle and threaded rod was selected to provide the necessary strength while minimizing the number and diameter of required holes. It was

also critical that holes for the bolts were not drilled or cored through any existing steel reinforcement.

Traditional reinforced concrete and epoxy doweled steel reinforcing was used to provide bending resistance for the walls at the slab interface. Perpendicular walls provide support at the walls' ends, leaving the midspan of the walls in need of reinforcement. New reinforced concrete pads were installed at critical locations at the base of the walls. The dowelled concrete pads served to enhance the wall-to-slab connection at the midspan of overstressed walls. These concrete pads were designed to be as thin and short as possible to minimize the loss of volume capacity of the tank.

Construction drawings were prepared detailing the type of strengthening solution required at each and every area of the tank. The complexity of the engineering calculations and construction drawings were a challenge, but the intricate design offered significant cost savings by reducing material costs and maintaining the required volume capacity of the treatment facility.

CONSTRUCTION

As this retrofit project was performed on a structure still under construction, many general conditions (for example, fencing, office, and utilities) were already in place. One scissor lift was craned into each cell of the structure. Two cells had floors that included large concrete elements. In these locations, scaffolding had to be custom installed to allow for access. Ambient winter air temperatures were too low to allow for carbon fiber retrofit at the time of year the repairs were needed. To create the needed temperatures, 134 hp heaters were craned into three locations and a 131 x 148 x 16 ft (39.9 x 45.1 x 4.8 m) clear-span tent was constructed to enclose the entire tank.

Cracks in the tank walls that developed during the filling for the leak testing were epoxy injected. Cracks, measuring over 3000 lineal ft (914.4 m), developed in two walls and were repaired using high-pressure, two-component epoxy injection.

The CFRP repair areas were laid out on the walls. The holes necessary for the steel assemblies were then drilled through the walls. The plan was to drill the holes using hammer drills, however, it quickly became apparent that it was not effective to precisely drill nearly 1000 18 in. (457.2 mm) deep holes in this manner. Ground-penetrating radar was used to locate existing reinforcing and holes were then drilled using core rigs. One challenge to drilling these holes was the precision required to be able to later install threaded rods through three locations connected in series and have the holes line up so that the prefabricated steel plates with holes would fit. Locations of holes were difficult to layout, drill, and install because they were required to be



External corner of structure showing CFRP, anchorage, and temporary tent erection



Bolts and plates at wall intersection (opposite side of wall pictured)



Ambient winter conditions required temporary heat and tenting of entire structure

in very specific locations while not cutting any existing reinforcing. Layout required measurement of steel thickness and carbon fiber thickness, both of which varied from row to row. The steel plates ranged up to 1 3/8 in. (34.9 mm) thick and steel bolts up to 1 1/8 in. (28.5 mm) diameter. Limited patching was required to repair failures and to



High-pressure epoxy injection of cracking



Saturating station in a single cell

smooth out some form lines. The repair areas were then floated smooth using an epoxy paste.

A central mixing and carbon-fiber cutting and saturating station was created in one of the central cells. The mixing station was able to simultaneously accommodate up to four installation crews all requiring specific individual material lengths in specific order. The wall surfaces were primed with impregnating resin. Unidirectional carbon fiber was installed by wet layup method at all locations. Over 8500 ft² (789.6 m²) of carbon fiber was installed in 4 days.

Following the curing of a carbon-fiber epoxy resin system, the holes for the steel bolts were redrilled through the carbon fiber. Hardened steel threaded rods were then installed (each sized for its specific location). Each steel member was field measured for the location of the holes through the steel and then field drilled by a magnetic drill. The hardened steel plates and angles were then installed in a full bed of epoxy. Hardened steel nuts and

washers were installed and torqued (each location again having unique tension requirements).

Carbon-fiber and steel assemblies were then all coated with a two-coat epoxy system to provide protection from the plant's operating environment. The two coats were different colors to help provide indication of the coating's condition in the future.

Holes were drilled into the floor and walls for the installation of epoxy-set dowels. After dowels were installed, steel reinforcing was installed and tied. Forms were set in place and concrete was installed using a pump crane.

Unforeseen conditions included blockouts encountered in the walls not contemplated in the original repair plan, along with existing reinforcing steel identified in locations not expected. When these unforeseen conditions were encountered, additional value engineering was used to create solutions that allowed the project to be completed with almost zero change in cost to the owner and further reduced the impact to the usable capacity of the tank. A crew of 16 craftsmen completed the entire project in 55 days.

SUCCESSFUL REPAIRS

The city of Camp Verde is delighted with the repairs to their new wastewater treatment facility. Every aspect of the project was riddled with challenges, including original design evaluation, repair design analysis, financial constraints, construction complexities, and weather. At several junctures, the project was nearly scrapped; and if not for the creative curtailing of the CFRP after extensive analysis and the unique application of bolts and steel plates, combined with the appropriate use of traditional concrete dowels, the project would not be the great success it is.

Camp Verde Wastewater Treatment Plant

OWNER

**Camp Verde Sanitary District
of Yavapai County**
Camp Verde, Arizona

PROJECT ENGINEER/DESIGNER

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REPAIR CONTRACTOR

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