CONCRETE SKIN GIVES NEW LIFE TO P_2O_5 REACTOR

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THE SITUATION

Central Phosphates, Inc., a subsidiary of CF Industries, Inc., is located ten miles north of Plant City, Florida. The plant was originally built in 1965, and was expanded in 1974. In the early summer of 1979, we were faced with a difficult decision regarding the Phosphoric Acid reactor in the fourteen-year old Dorr-Oliver plant. This fifty-foot diameter and twenty-foot high tank was in need of extensive repair following many years of faithful service during which a series of minor repairs and turnarounds were completed. At this time, we were faced with another "patch-job" at a cost of plus or minus $50,000 and approximately nine days shut-down. There was no positive assurance that this temporary repair would last until the following year's turnaround, and it was possible that the reactor would require additional repairs within the next several months. After fourteen years of patching the patches, it was apparent that this reactor was in need of a major overhaul or replacement. The needed extensive brick, rubber, and steel repairs were estimated to cost $475,000, but more importantly, the repairs would have necessitated a plant outage of approximately twenty-eight days. The market demand for fertilizer at the time made this extended outage extremely undesirable and it was apparent that we must consider some alternate approach.

ALTERNATE APPROACH

The idea of encapsulating the bottom and sides of this reactor with concrete had been considered on several occasions in the past and, for any number of reasons, had been discarded. In a manner of speaking, our backs were against the wall and we were faced with the tough decision of how to properly repair this tank and, at the same time, avoid the undesirable plant outage. In May, 1979, we began to develop the scope for this encapsulation with Pridgen Engineering Company, a division of Jacobs Engineering Group, Inc. In a matter of weeks, we jointly developed the design criteria and a cost estimate upon which emergency approval was granted to go ahead with the project.

Generally, the encapsulation required a twenty-inch-thick bottom slab and a fourteen-inch thick circumferential wall of concrete using the reactor shell itself as the interior form. This approach was quite feasible in view of the fact that the reactor was resting upon concrete piers and steel grillage beams. When the project was approved for construction, our estimate indicated that the encapsulation would be $125,000 less expensive than the massive repair alternative; but, the most favorable consideration was that this encapsulation would cause us a downtime counted in hours rather than in terms of several days. The vast majority of the encapsulation work was accomplished while the reactor was in operation and the total budgeted construction time was from late May until mid-September, 1979. In the final analysis, the cost was less than the budgeted amount and the construction schedule was maintained.

DESIGN CONSIDERATIONS

The design of the concrete encapsulation of the reactor progressed in three stages. Initially, the soil bearing capacity had to be determined in order to decide if it was feasible to support the additional weight of the concrete with the existing foundations. Secondly, the concrete floor and walls were designed to determine thicknesses and reinforcing requirements. Finally, the details of the encapsulation were designed to improve the durability of the concrete, facilitate construction, minimize leakage, allow for expansion, and reduce plant operational outage.

To determine the suitability of the existing foundations, the weight of the concrete roof, floor, and walls were estimated. It was found that the additional pressure imposed by the footings on the soil would be 500 psf greater than the existing 3,000 psf. The thickness and reinforcement of the existing foundations were checked and found to be capable of supporting the load. A local soil consultant made two borings near the reactor to determine how the soil would respond to the additional load. His analysis indicated that the additional loads would cause a settlement of approximately one-half inch. Since this amount of settlement would cause no problems, the decision to proceed with the project was made.

The structural design of the reactor floor was undertaken next. The existing steel floor was supported by steel grillage on twenty inch centers spanning ten-feet six-inches between concrete pier walls. This steel was to remain in place during construction, but it could not be considered as effective support in designing the concrete because of eventual exposure to phosphoric acid. The floor was designed to encase the existing grillage beams with the principal reinforcing running parallel to them. Because of the reduced thickness of the concrete at each pier wall, substantial vertical and diagonal reinforcement was used to obtain the desired shear strength. To support the floor and walls around the edges of the reactor, additions to the pier walls were designed to carry the loads to the existing foundations. The principal reinforcing steel in the walls was designed to resist the hoop tension imposed by the contents of the reactor. As with the grillage, the existing shell was considered to be structurally ineffective due to eventual exposure to phosphoric acid.

To improve the chemical resistivity of the concrete, a special mix was recommended by the concrete supplier. The concrete used was a 4,000 psi mix made from type "I" cement. Fly ash was added to improve durability. River gravel, instead of limestone, was used for the coarse aggregate. The concrete was proportioned to provide a five-inch slump to facilitate pumping of the mixture.

To allow for inserting the pumping equipment under the existing floor, the reinforcing steel was designed to provide an open area at the center of each span for the entire width of the reactor. A construction joint in the wall was placed six ft. above the bottom of the concrete floor to provide a pressure head of plastic concrete during construction to minimize voids.

The existing steel shell was coated with urethane foam to insulate the concrete from the hot contents of the reactor so the concrete could be cast while the reactor was operating. This foam also allowed expansion of the steel shell within the concrete shell.

To minimize leakage, stainless steel sheeting was installed under each grillage beam where it rests on the concrete pier walls. Stainless steel sheet was also used to prevent seepage at construction joints.

To allow for expansion of the concrete floor over its supports, stainless steel sheets were used as bond breakers at all contact points. Vertical contact surfaces between the floor slab and the support piers were faced with premolded joint filler to allow expansion to occur.

Most of the operational downtime for the reactor would have been required to remove old nozzles from the shell and install extended ones in order to protrude through the new concrete shell. This downtime was avoided by using oversized stainless steel nozzles welded to the shell around the existing nozzles. These nozzles were provided with shear connectors and seepage prevention plates. After the concrete was cast, the old nozzles were cut from within the new ones during a minimal downtime. Connection of the new nozzles to existing piping was then made.

CONSTRUCTION PROGRESS

The actual construction was accomplished by a combination of CF Industries' maintenance mechanics and contract maintenance personnel from Lakeland Construction Company. The initial activity was to remove the north half of the concrete paving beneath the reactor so that excavation and forming could be done for the additional beams and piers which were required to extend up from the existing spread footers. After this work was accomplished and these piers were poured and finished, the south half of the concrete paving was removed and similar excavation, forming, and pouring was accomplished there. While this work was going on, rebar was being installed beneath the reactor, and the new embedded nozzles were being installed along the perimeter of the reactor. After the south side piers were finished and the back fill and repouring of the paving slab was accomplished, it was almost time to prepare for the 160 cubic yard pour of the reactor floor and a portion of the side.

After the rebar and embedded items were installed beneath the reactor and four feet up the side, the reactor was cleaned and sprayed with a thin coating of urethane insulation. Forms were installed and preparations were made for the pumping of the concrete which was to begin at midnight and extend for six to eight hours until finished. In order to ensure the best concrete cure, the reactor was shut down and drained in a matter of hours before this critical pour. There was not much concern at this time of the effect of temperature on the concrete cure time, since there was an adequate insulating layer of gypsum inside on the bottom and sides of the reactor. A concrete pumper and associated equipment was brought in for this work, and a standby pumper was brought in for use in case of an emergency.

This bottom pour was accomplished in good order, the reactor was immediately brought back on line, and work began on installing rebar and forms for the remainder of the twenty ft. vertical side of the reactor. When this forming work was completed, a similar midnight arrangement was made for this final pour which was accomplished in early September, 1979.

RESULTS

After the forms had been stripped away and all scaffolding dismantled, a number of voids became apparent in the side and the bottom of the new concrete shell. These voids were patched from the outside, but their mere presence indicated that there may have been additional voids on the inside and that rebar may have been exposed to acid attack. In early October, we employed the services of a consultant through the Portland Cement Association and used sonic techniques to investigate the possibility of interior voids in the concrete shell. This investigation did, in fact, verify that there were voids in areas which corresponded with apparent voids on the exterior.

We recognized from the very beginning that pumping concrete in this manner across the entire diameter of a fifty ft. vessel would not be easy. In spite of our best efforts to ensure the best grade of pumpable concrete and in spite of our best efforts in manning and inspecting the work, voids did appear and are currently of some concern to us. In February, 1979, during a scheduled turnaround of this reactor, we opened the interior and exposed two voids: one on the bottom, and one on the side, by stripping away the interior brick, rubber, and steel. The sidewall void was less extensive than we had anticipated and was easily patched. The bottom void was approximately six ft. in diameter and had seeped acid for several weeks before the turnaround. However, it was apparent that the void had not filled with acid and that the rebar was undamaged. In a manner similar to the side wall, this void was patched from the interior and recovered with steel, rubber, and acid brick.

The complete job was finished by the extension of the agitator support superstructure out to the new concrete shell.

FUTURE WORK

Plans have been made to finish this encapsulation with a concrete top on this reactor. We expect to accomplish this work sometime during 1980. The design for this top has been completed and a general description of the design considerations follows.

> The main loading of the reactor top is from the large agitators. These are supported by stringers that span radially around the reactor from the center well to the outer steel shell. Extensions for these stringers were designed to carry the load to the new concrete shell. The interior portion of these support members is welded to the existing steel roof so that the roof shell acts as the bottom flange of the member. Because of eventual corrosion of the roof shell after the concrete is cast, it was necessary to design a stainless steel bottom flange for this portion of the members. This new flange, spanning between the radial beams, also provides support for the new concrete roof. For the outer portion of the radial beams, where the beams are not in contact with the roof surface, due to the slope of the roof, the concrete roof had to be supported by a new concrete beam spanning between the concrete shell and its contact point with the steel radial beam. To support the additional load imposed by the concrete roof, the radial beams were reinforced with steel plates welded to the flanges.

SUMMARY AND RECOGNITION

In the final analysis, we are quite pleased with the cost, schedule, and minimal downtime factors associated with this concrete encapsulation project. Our few seepage and void problems have been identified and we are overcoming them in a stepwise fashion. If we had this job to do over again, there are a number of additional techniques and inspections that we would perform in order to better ensure a more perfect pour. The primary change would be to design the sidewalls for two pours, instead of the one pour used.

It is appropriate that we recognize the several companies and individuals who played a role in making this job as successful as it was. It was truly a joint effort by many, and we are very grateful for their assistance. First and foremost, we wish to recognize Pridgen Engineering for their design and consulting services. The concrete pumping was accomplished by Hercules Concrete Pumping Service, and the concrete was supplied by Ewell. As we have described, the concrete used was a very special admix, and we wish to recognize Ideal Basic Industries, Cememt Division, and Monier Resources, Inc. Finally, we would like to thank and congratulate Joe Dalton, CF's Maintenance Superintendent, who was in charge of the entire field activity, and Gene Bridges, Construction Supervisor for Lakeland Construction Company.

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Mr. Bogart will present the paper.