November 2006

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The two phosphoric acid storage t

Gunung Putri completes world's largest GRP chemical storage tanks

Alfred L. Newberry of FEMech Engineering describes how two 5000 m^3 phosphoric acid storage tanks were produced from composites for an Indonesian fertiliser plant.

Pt Gunung Putri Graha Mas of Jakarta, Indonesia, has recently completed fabrication of two 5000 m^3 (1.3 million gallon) phosphoric acid tanks. These large storage tanks are part of a new fertiliser plant located in Indonesia. The fertiliser plant is a new addition to the infrastructure of a large palm oil producer. The fertiliser from this plant will be used for the palm tree estates and will replace fertiliser which, in the past, was purchased from outside firms.

The two tanks are the world's largest glass fibre reinforced plastic (GRP) chemical storage tanks, having a diameter of 20 m (65.6 ft) and a shell height of 15.8 m (51.8 ft). The design specific gravity for the tanks is 1.8, which results in a liquid head pressure of 28.4 m (93.2 ft) water column or 282 kPa (40.3 psi). Each filled vessel will weigh in excess of 9000 tonnes.

One of the basic raw materials for commercial fertiliser production is phosphoric acid. In order to obtain the best price and keep shipping costs to a minimum, phosphoric acid must be purchased in ship load quantities. Each tank is large enough to hold a ship load of acid. The plant operators must coordinate the arrival of the tanker ships with the emptying of one of the GRP tanks so there will be no delay in off loading. Incoming tankers will arrive at a jetty, which supports the GRP piping for transfer of the acid to the tanks. Gunung Putri fabricated and installed the transfer piping in addition to numerous other vessels and components in the fertiliser plant.

The 'super big' tanks, as they are called at Gunung Putri, were designed by FEMech Engineering of Harrison, Arkansas, USA.

Tank knuckle being rotated for winding.

Gunung Putri also obtained the basic large diameter winder design and winder software from FEMech.

Jobsite challenges

An old adage warns 'this is not for the faint-hearted.' This was certainly applicable to the fabrication of these giant tanks and many aspects of the job created serious challenges for the management and production personnel of Gunung Putri. Some of the challenges were expected and some were unexpected.

Many aspects of the job created serious challenges.

The remote location of the jobsite and the great distance from Jakarta created many expected challenges. Indonesia is a vast country and, as anticipated, it was not always easy getting large numbers of personnel, heavy equipment and huge quantities of materials to the jobsite.

There is no commercial airline service to this area so it is necessary for management and consultants to fly to a not-so-nearby city and travel by road to the jobsite. It takes about 12 hours to travel from Jakarta to the jobsite.

Rain is always an issue in Indonesia but in perfect accord with Murphy's Law, there was extra heavy rainfall during much of the fabrication period. In addition to slowing fabrication, the heavy rainfall made transportation of materials and personnel more difficult than usual.

The most unexpected jobsite challenge was soft soil. The soil bearing strength was very low and was made even lower by the heavy rainfall. Those involved in the job aptly dubbed the soil 'jelly'. The poor soil properties hampered movement of equipment and materials and also allowed the winder foundation to settle and tilt, which caused problems and delays.

Wound-on knuckle

One of the advanced features of the tank fabrication is the wound-on knuckle. This has never been done prior to this job in a large diameter GRP tank and is a world's first.

The feat was accomplished by first turning over each knuckle and setting it on the winder. The bottom can was to be wound onto the knuckle, which had been carefully moulded per the finite element analysis (FEA) design.

Gunung Putri has exceptional mould makers. The two gigantic female moulds made for these knuckles were ingeniously fabricated from plywood. The resulting knuckles had a very precise outside diameter (which was critical, since the anchor bolts were cast into the foundation), were moulded to the correct shape per the FEA design and fit the foundation very well. Foundation fit-up is a critical issue which can be easily overlooked by those whose experience is limited to small diameter tanks.

Once the winding was complete, the knuckle and bottom can were turned over again and set on the tank foundation. It might be noted that the soft soil was an asset during the knuckle flipping process in providing a soft surface for this multi-step lift.

There were several important reasons why this design and fabrication technique were chosen. For a tank of such a huge size and high liquid density, there are only two options for the bottom knuckle; a flex knuckle or a monolithically moulded hard knuckle.

A hard knuckle is the superior design for resisting high seismic loads. The seismic shear loads are very large given the high seismic zone and the large diameter, height and liquid density of the tanks. A hard knuckle is geometrically very stiff as compared to a flex knuckle. A wound on knuckle creates lower discontinuity stresses than a secondary bond attached hard knuckle. Also, a wound-on knuckle requires significantly less labour and material than a secondary bond attachment.

Serendipity from resin shrinkage

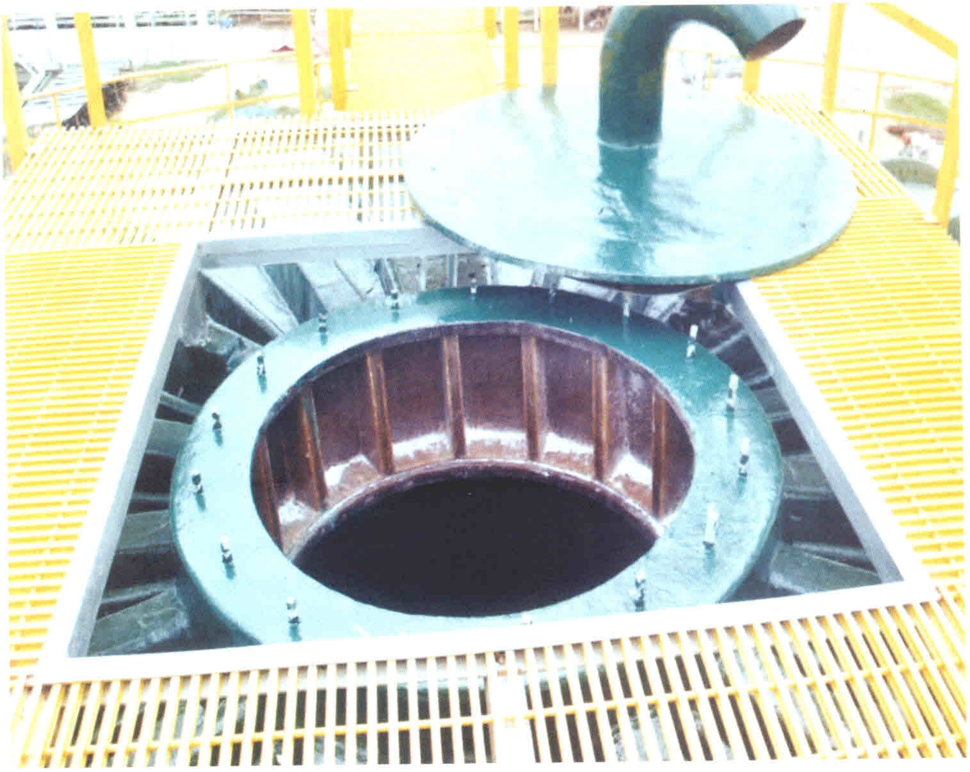
Resin shrinkage results in a change of part geometry. Shrinkage is sometimes an advantage and sometimes a disadvantage. In the case of a flange, resin shrinkage is problematic and must be carefully controlled by tool compensation and consistency of material and working environment. In the case of centrifugally moulded pipe, resin shrinkage is an advantage causing the pipe to shrink, which allows the part to be easily extracted from the female mandrel.

The huge knuckles were moulded to a width of approximately 4 m creating an annular ring with an open area of approximately 12 m diameter. The flat bottom in this centre region is essentially in a zero-stress state since it is fully supported and the stress fields from the knuckle have died out prior to reaching this area. This area was filled with factory moulded panels which were bonded together.

As the knuckles were fabricated the inner annular edge raised off the concrete pad due to resin shrinkage. By the completion, the drawback was in the order of 150-200 mm. In this case, shrinkage was used to advantage. After the knuckle and bottom can were placed back on the foundation, a dam was created in the centre opening. The drawback area was filled with non-shrink grout, which created a perfect fit between the bottom and the foundation. After the grout was set, the dam was removed and the centre area was poured with concrete and trowelled smooth. After adequate time for curing, the centre area was filled with factory-moulded panels and these were laminated in place.

The drawback in the moulded knuckle created an annular gutter area in the bottom, making it easier for the factory personnel to periodically clean the tank. The customer's engineers had been concerned about the difficulty of cleaning a flat bottom and so resin shrinkage provided a serendipitous solution to that concern.

The top can and dish assembly being lifted into position.



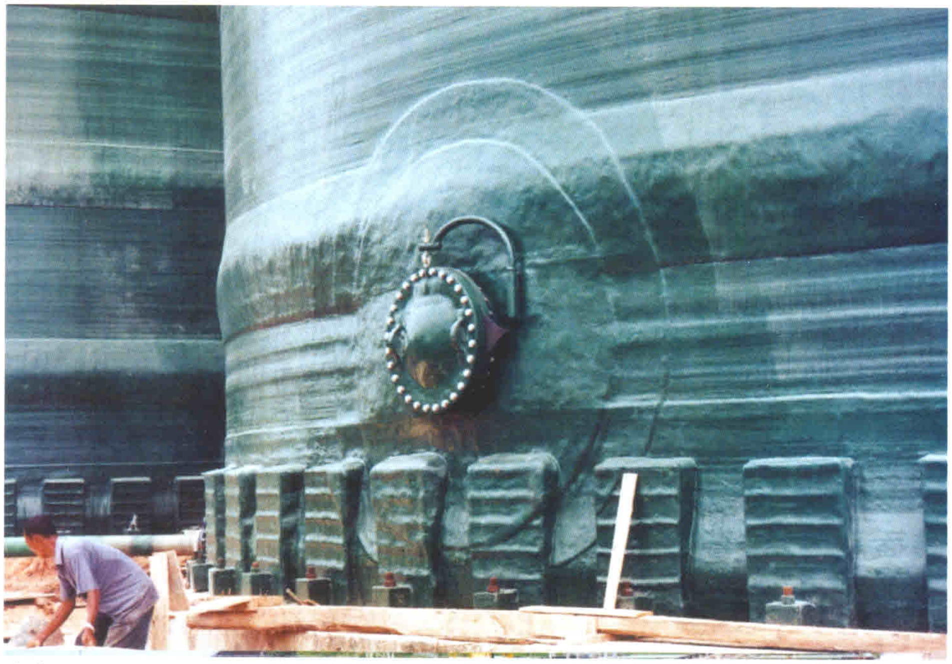
The large compression ring at the top of the dish.

Segmented domed top

The tank is directly vented so the dome was designed for gravity, wind uplift and stiffening of the shell for seismic loads. FEA studies indicate that a dished top is the most practical way to stiffen the top edge of a large diameter tank shell. FEMech has recently completed the design of a 18.6 m by 21 m high FRP tank with a design specific gravity of 1.20 and significantly lower seismic acceleration as compared to the Gunung Putri acid tanks. These 18.6 m tanks are open top and require a huge 760 mm steel W beam

Gunung Putri

Gunung Putri supplies the Indonesian market with tanks, scrubbers, pipe, duct, cooling towers etc., and has exported GRP products to Japan, Hong Kong, Singapore and other countries for many years. The general manager of Gunung Putri is Mr Abraham Lim, who founded the company in 1988 in Bekasi, a suburb of Jakarta. The acid tank project manager is Mr Gunawan Karim, who has been employed by Gunung Putri for 13 years and is also in charge of production at the Gunung Putri facility in Jakarta.



The large anchor lugs and the side manway.

An aerial view of the two huge acid tanks.

to support the seismic loads. If these were domed top tanks, no top stiffener would be required.

The domes were made in 16 segments each with a large trapezoidal stiffener. The segments are joined in the centre to a large C-shaped compression ring. Once again, Gunung Putri's mould making expertise served this project well. In the case of segmented domes, any error is multiplied by the number of segments. If a segment is made 5 mm too wide, the sum is 80 mm which is a very significant dimensional stack up. Due to excellent moulds, years of hand lay-up experience and careful attention to detail, the domed tops went together with relative ease and are among the finest large diameter domes which have ever been fabricated.

Filament winding

Each large cylindrical shell is made in five cans using a stepped wall design. The cans are hoop wound and reinforced with 800 g/m^2 unidirectional stitched fabric for axial strength and stiffness.

The bottom can is over 90 mm thick which is massively thick. The manway cut-out is so large and heavy it takes two strong men to move it around. Several sample blocks were cut from one of the cut-outs and the edges polished. The laminate has very little air entrapment and the roving wet out is very good.

Huge quantities of raw materials

The quantities of raw material and man-hours required for the fabrication of these enormous tanks are somewhat astounding.

For the two tanks, 250 tons of resin was required which equates to about 14 each 40 ft shipping containers. For the two tanks, 54 tons of chopped strand mat, 54 tons of woven roving, 111 tons of winding roving and 13 tons of warp unidirectional were required. This would be 13 each 40 ft shipping containers of glass reinforcement.

About 50 000 man-hours were required for each tank. This number is higher than Gunung Putri expects in the future for similar projects. This project was a giant leap for Gunung Putri and provided a steep learning curve which will benefit them greatly on future large field projects. It should also be noted that in Indonesia, the ratio of material to labour costs is relatively high, so fabricators in this region will employ more man-hours for a given project than a fabricator in the USA or Europe, where the ratio is quite different.

Because the jobsite is remote and because the job was almost a year in progress, a dormitory and office facility were built on the jobsite. The facility was complete with a kitchen and laundry. Two full-time cooks were required to feed the large crew deployed for this project. ■

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