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Advantages of bolted tank construction for paste thickeners

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Abstract

For liquid containment tanks there are many benefits in using bolted joint construction rather than site welding. Some of these include faster assembly time, better quality surface treatments, lower site costs from reduced personnel and equipment, and the ability to easily move the tank to a different location. These factors make bolted tank construction attractive to many industries. However, in thickening applications the vast majority of tanks are site welded.

There are two key reasons why thickener users do not consider bolted tank construction more often:

- *a higher capital cost for the thickener due to the significant number of bolts, flanges and associated fabrication costs*
- *uncertainty about the design of a safe and reliable bolted joint, especially for larger tanks.*

Both of these considerations are important and should be evaluated carefully. Often, the higher initial capital cost will translate into total project savings by replacing hundreds of metres of site welds and painting with simple bolt tightening and torque inspection. For a typical welded thickener installation of 12 weeks it is common for an equivalent bolted design to take four to six weeks with less manpower.

Confidence in joint design comes down to good engineering, testing and field experience. If all three of these conditions are met then the risk of leaking joints is minimal.

This paper presents some comparisons of bolted and welded tank designs for paste thickeners and evaluates the total cost, time and risk considerations for each. Some examples of successful bolted thickener installations are shown.

1 Introduction

The two methods of thickener tank construction used by Outotec are site bolted joints and site welded joints. An example of each is shown in Figure 1.

Figure 1 18 m bolted paste thickener (left) and 42 m welded high compression thickener (right)

Twenty years experience and greater than 50 installations have shown that bolted designs are both reliable and economically competitive against welded designs. Even so, only 2–3% of the thickeners built by Outotec are bolted.

Bolted designs utilise more steel and require extra fabrication time; but more of this time is spent in the workshop and significantly less time is spent at the installation site (50–75% less). It is difficult to perform an absolute cost comparison between a bolted and welded thickener tank design since steel prices change from year to year and because of the large disparity in labour rates between countries. However, there are several key factors that will favour bolted thickener construction:

- Higher labour rates: maximising workshop hours and minimising worksite hours is more efficient and cost effective.
- Poor climatic conditions: frequent rain, snow and cold weather make site-welding and surface treatment costly and time consuming.
- Remote locations: welded installations require more skilled personnel and equipment, hence getting resources to isolated sites is problematic.
- Severe time constraints: more workshop hours means that additional personnel and nightshifts can be utilised to fast-track delivery.
- Mineral sands: large, unconnected ore bodies make thickener relocation desirable, which is facilitated by bolted construction.

Outotec believes modular bolted thickener tank designs offer many benefits and will increase in popularity as customers gain a full understanding of the advantages offered by this type of construction. The applications for this technology continue to expand and the installation of four 43 m bolted paste thickeners in Peru this year should reinforce the viability and importance of this modular design.

2 Overview of bolted tank design and installation

The construction and installation of bolted thickener tanks is unlike any other tank design on the market. As such, it is not covered by a standard or code. The following sections outline the unique aspects of this design.

2.1 Joint design

Outotec utilises a flanged joint for its bolted thickeners whereas the more common joint found in liquid and bulk storage tanks is a lap joint. These are both shown in Figure 2.

There are only a few design codes that utilise flanged joints. The American Petroleum Institute (API) Specification 12B (2008) uses a combination of lap joints and flange joints, but only for relatively small oil storage tanks. When these joints were trialled on increasingly larger tanks, design failures started to occur. The only other common codes that utilise flanged joints are those for pressure vessels. The design philosophy for these codes is sound but also highly conservative since they are meant to seal high pressure gas in relatively small tanks rather than large slurry tanks at atmospheric pressure.

Even though lap joints require more bolts compared to flanged joints, it’s found that for storage tanks they utilise less steel, are better suited to mass production and can be scaled up to very large tank sizes. Lap joints are found in many current tank standards such as those published by the American Water Works Association (AWWA D103). Despite all of these points, Outotec has found the flanged joint to be more practical in thickener construction. Thickeners are not mass produced so the reduced number of bolts and the simplicity of the flanged design are important.

In the absence of any modern flanged design code for large tanks, Outotec has completed significant research into the performance of these joints under design pressures as found in high specific gravity (SG) paste thickeners. The combination of thick flanges with thinner wall thicknesses produces some unique joint behaviour. With this work completed, Outotec is confident that the safety factor of the joint exceeds that of the tank shell and that all of the problems encountered with such codes as API 12B (2008) have been resolved.

Figure 2 Flanged joints on thickener (top) versus lap joints on water tank (bottom)

2.2 Tank design and installation

Bolted thickener tanks are constructed of several pie shaped floor sections and curved wall panels. Structurally, they are no different to a typical welded thickener. Cradles are made for stacking several floor or wall sections together to facilitate easy transport and protection of these items to site. Figure 3 shows the installation of floor and wall sections on a 33 m high compression thickener.

After floor sections are moved into place on the supporting columns, a cherry picker or scissor lift can be used by a worker to access the bolting flanges. It is found that bolt tightening can be performed at a rate of 2–3 m per hour depending on bolt spacing. In contrast, site-welding is closer to 0.7 m per hour (when accounting for double passes on butt welds) and does not include the time needed for radiographic or ultrasonic testing.

All welding for bolted tanks is performed under controlled conditions in the workshop and the full tank can be trial assembled to ensure accurate fabrication tolerances and ease of construction at site. Surface treatments are applied in the workshop under the correct temperature and humidity, rather than outside in the elements. In effect, all of the hard work is done in the shop and site installation is greatly simplified.

That said, there is still some experience and expertise required for proper assembly and it is important that certain procedures are followed. As simple as it seems, fastening the bolts in the correct order is essential.

There are other potential problems that are easily avoided with experienced project management and supervision.

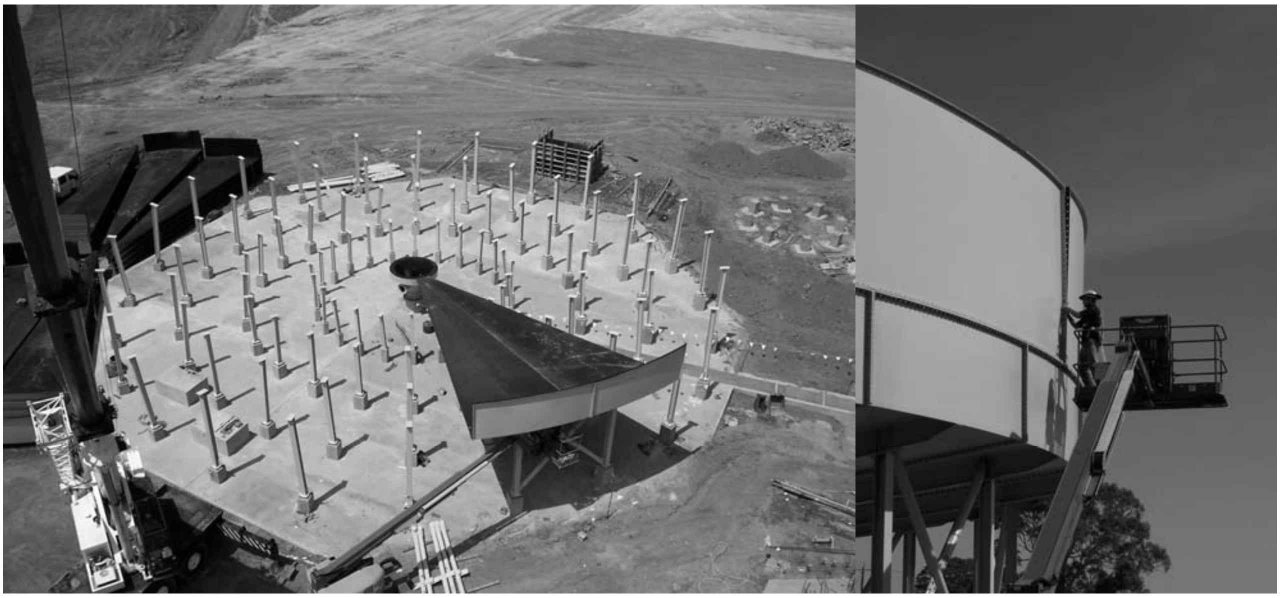

Figure 3 Installation of thickener floor and wall sections

3 Comparison of bolted and welded thickener construction

In 2008, Outotec commissioned a report from JV Engineering in Australia to compare a bolted versus a welded thickener design for a mineral sands project. The aim was to evaluate the risk, time, cost and quality considerations for fabrication and site installation; JV was ideal for this role since they provide both of these services.

To make the comparisons fair, the welded and bolted options had the same size and number of pieces (18 floor and nine wall sections) to transport to site. This meant they would have the same on site joint lengths and transport costs would be similar. Both painted and rubber-lined options were considered. The welded option would be painted/rubber lined in the workshop apart from a 500 mm weld margin either side of site welded areas. The bolted option would be painted/rubber lined 100% ex works.

The following sections detail the main findings from the report.

3.1 Risk

The most notable finding from this section of the report was that a welded thickener was considered riskier in every respect. JV Engineering had installed dozens of bolted thickeners and had no problems with leaking; therefore it was not listed as a genuine risk. Following are the lower risks associated with a bolted design:

- Fewer installation delays: the bolted option requires less than a third of the site man hours of the welded option therefore reducing the risk of inclement weather and industrial action that may affect the site.
- Safer site installation: the number of activities on site that would be required to have safe work method statements, job safety analyses (JSAs) and risk assessments are significantly higher on the welded option. These activities include welding, grinding, blasting, painting, rubber lining, confined space time and working at heights.
- Lower risk of damage to paint or rubber: with the bolted option no hot works have to be carried out on site.

3.2 Time

The report concluded that if there were no significant delays on site, then start to finish times of both options would be similar. However, anyone with site experience knows that unexpected problems do occur; therefore, it can be said that the bolted option offers a greatly reduced chance of schedule delays. The bolted option staying in the workshop for a greater percentage of the schedule also had the following advantages:

- easier fast tracking with nightshift and extra resources if required
- better access to materials and equipment at the workshop for late design changes.

3.3 Cost

The estimated cost for fabricating and installing the tank wall and floor is given in Table 1. The support columns were the same for both designs so were excluded from the analysis. It was in JV's best interest to account for all costs accurately and recommend the lowest price option so that they would win the project. Figures are for comparative purposes only and the thickener diameter isn't disclosed to maintain commercial-in-confidence.

Table 1 Cost comparison between bolted and welded thickener options

	Bolted and Painted	Bolted and Rubber Lined	Welded and Painted	Welded and Rubber Lined
Fabrication cost	$688,640	$688,640	$576,240	$576,240
Shop paint/rubber	$219,740	$538,246	$205,000	$518,246
Site install	$48,000	$91,200	$357,840	$723,220
Total	$956,380	$1,318,086	$1,139,080	$1,817,706

Some of the cost items taken into consideration when welding, painting and rubber lining onsite include:

- extra crane time due to longer site duration
- extra contractors required on site
- longer scaffold times
- more mobilisations, airfares and inductions
- extra time for vehicles, facilities and crib hut
- hire of welding machines and ancillary equipment
- site inefficiencies.

For the painted option, the analysis above shows that the total installed cost for this thickener tank (excluding columns) will be 16% less if bolted. This is despite the fabrication cost ex works being approximately 20% higher. The difference for the rubber lined option is even more striking with a reduced cost of 27% for the bolted version.

Ordinarily, a 20% price increase ex-works would be a deal breaker. However, in this case it could be shown to the customer that total project savings would be delivered.

3.4 Quality

Perhaps the most important but less obvious consideration is the quality of the final product. Figure 4 shows an example of a 33 m thickener complete with support structure, bridge and internal mechanism that took three weeks from start to final completion using only six men. Despite such rapid deployment, quality could be guaranteed on a bolted design because of the following points detailed in the report:

- Assembly and welding can be planned and carried out more efficiently in the workshop by the use of jigs with constant monitoring of quality. Work pieces can be manoeuvred to ideal weld positions.
- Blending of welds required for rubber lining can be carried out in a controlled environment and checked before leaving the workshop.
- Inspection by third party can be planned and coordinated with easy access for inspection.
- Painting and rubber lining can be applied indoors, under controlled conditions where the quality can be monitored efficiently.
- No welding inspections or non-destructive testing (NDT) occurs on-site; only tolerance and bolt torque inspection is required.

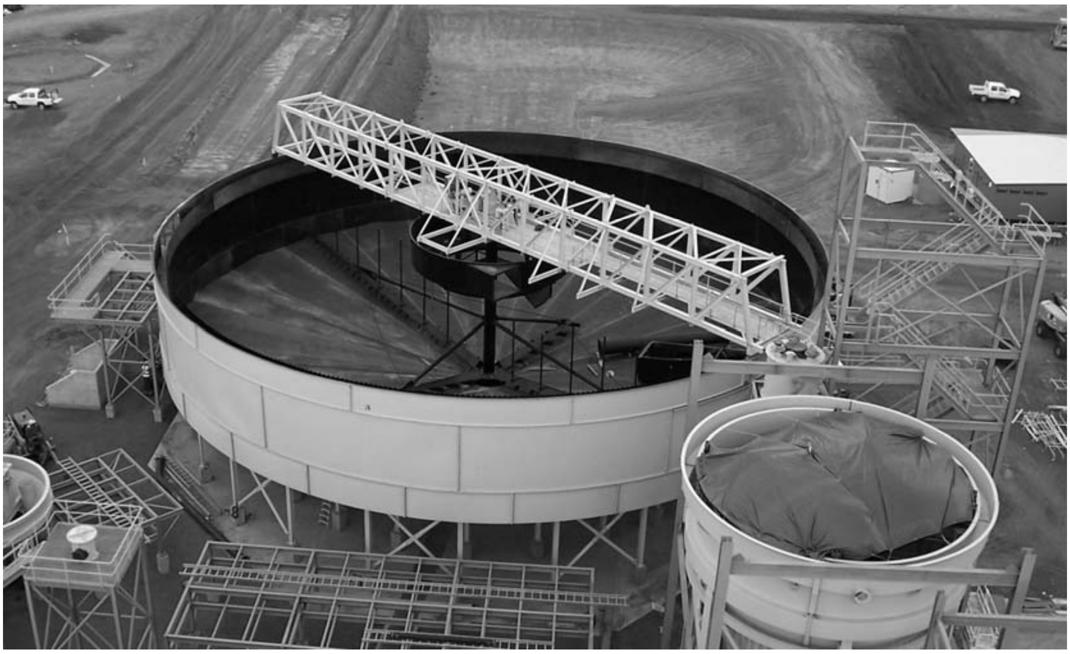

Figure 4 Example of 33 m thickener installation completed by six men in three weeks

4 Case study – Toromocho 43 m copper tailings paste thickeners

In late 2009, Outotec was awarded the construction of four copper tailings paste thickeners at the Toromocho mine in Peru. The 43 m diameter thickeners will produce an underflow of 70% solids content by weight with a 250 Pa yield stress, making them some of the largest paste thickeners in the world. The design slurry feed rate for each thickener will be 4,460 tonnes per hour and a shear thinning loop will be provided to ensure that the underflow can be moved by the pumping system. All four thickeners will use a bolted tank design due to the remote site location and poor weather conditions. Six concentrate thickeners of 41, 22, 15, 10, 7.5 and 5 m will also be provided in a modular bolted design.

To minimise the disruption to local towns and roadways, a very demanding 4 m width and 4 m height restriction is preferred by the client. Combined with high seismicity in the area, the design challenges for these thickeners are many.

Mount Toromocho is located approximately 140 km east of Lima by road and the mineral deposit is at a very high elevation ranging from 4,700 m to 4,900 m above sea level. Altitude sickness commonly occurs above 2,400 m. The nearest town is Morococha, shown in Figure 5. It has a population of 6,500 at an elevation of 4,600 m. The climate of the mining district is very cold with a mean average temperature of 5 to 7°C. The wet season from November to April has frequent hail, rain and snow falls, making construction activities difficult. The frequency of electrical storms is high.

To add more uncertainty, mineworker strikes in Peru are fairly common as unions negotiate conditions in a country where over 25% of gross national product (GNP) comes from mining. Nationwide strikes have occurred in 2007, 2008 and 2009. Minimising construction time is therefore a big priority.

Figure 5 Town of Morococha, Peru near the Toromocho mine

API Standard 650 (2009), Welded Steel Tanks for Oil Storage, is a commonly followed code for process tanks such as thickeners. An important consideration for this project was that the code strictly prohibits any welding when surfaces are wet from rain, snow, or ice or during periods of high winds. Also, it states that the steel temperature must be preheated to a minimum of 0°C before welding if conditions are below freezing. Conversely, there are no such restrictions on bolt tightening and therefore the design of the tailings and concentrate thickeners facilitates installation during any part of the year.

Site welding itself generally takes more skill than shop welding. Optimal welding is achieved in the down hand or horizontal welding positions, which can easily be achieved in the workshop. However, thickeners welded on site require many vertical up welds and difficult overhead welds. Combined with possible altitude sickness at Toromocho, these difficult welds become very slow and potentially dangerous to tradesmen. Though cost and time helped dictate a bolted design for this project, it can be said that safety was also important.

Figure 6 shows the planned tank partitions for the 43 m paste thickeners based on the 4 × 4 m transport envelope. Each tank will have a total of 86 pieces for the floor and wall. The challenge on a tank this size is to build and transport all of these pieces from a workshop in Lima to the mine site and still have them fit together with millimetre precision. This is entirely achievable, but will require some fabrication expertise from Australia since relatively few bolted thickeners have been built in Peru.

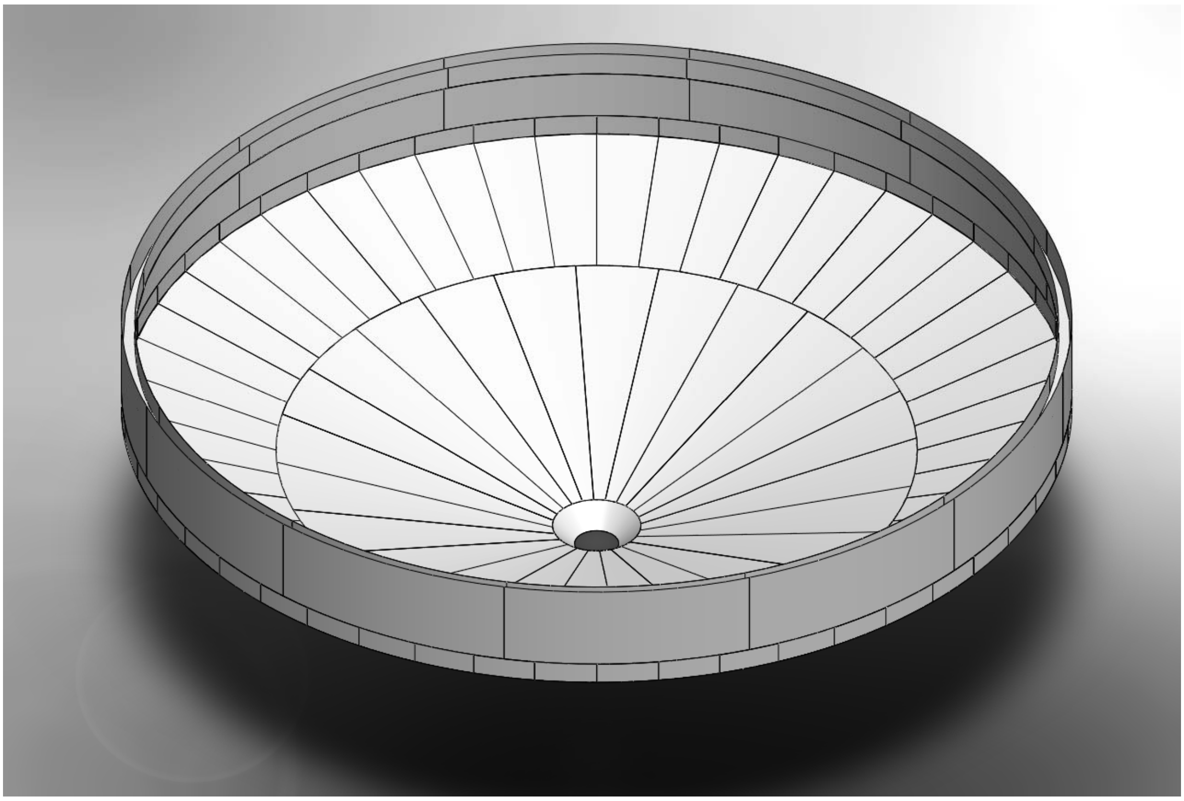

Figure 6 Tank partitions for 43 m paste thickeners

5 Conclusion

This paper has shown that bolted tank construction for thickeners can be both reliable and cost competitive against typical welded designs. In many instances, the final quality of the tank will also be better. Based on Outotec's experience, modular tank designs are under utilised in the thickener industry.

To properly compare the benefits of bolted versus welded thickener construction, the many considerations for fabrication and installation highlighted in this paper should be evaluated. If this is done regularly for prospective thickener projects then bolted tanks should become more common.

Acknowledgements

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