

Hanging by a Thread: Saving the Tone Works Tank from Collapse

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Abstract

How do you save an old and fragile cast iron tank from collapse? Thought to be 19th century, it's the size of a small house and suspended two metres above the ground. Already dangerously close to crashing down on decaying supports, it's too unsafe to prop it from below. And as part of the Grade II* listed Tone Works, a former textile mill, a piece of social and technological history was at stake. With collaboration between the design team and contractor at the heart of our approach, we developed a solution which hung the tank from steel beams and lifted it millimetres off its supports using two hydraulic jacks and virtually no temporary works. Connecting to the tank safely and without damaging it was achieved using an innovative detail that clamped onto a lip around the top of the tank, safeguarding part of the Tone Works story for future generations.

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Introduction

Tone Works is a former textile works in Wellington, Somerset. It was built by the Fox Brothers between 1830 – 1913 to wash, mill and dye cloth. Deterioration of the buildings and asbestos contamination led to abandonment of the 2-acre site in 2000.

It lay untouched for two decades until coming into the possession of Somerset Council. Under the guidance of Thread architects, careful exploration revealed a patchwork of beautiful buildings and the most complete set of historical textile finishing machinery in the country. The site is Grade II* listed and efforts are underway to conserve it.

A small part of this project lies in the Dye Store, a brick and stone masonry building which was retrofitted in the 19th century with a cast-iron tank at first floor level. Constructed in-situ from large panels, it measures 11m

long, 7m wide and 2.9m deep. It weighs 30 tonnes when empty. The tank was originally part of a water-softening apparatus and then stored fuel-oil. Suspended 2m above the ground, it is an imposing piece of engineering and an unashamedly pragmatic alteration of an existing building to keep up with the technology of the time.



Figure 1 The tank was obscured by the collapsed roof trusses, debris and vegetation

The beams, columns and props supporting the tank were decaying after decades of water ingress, the roof having collapsed some 30 years ago. Collapse of the tank was a real possibility. One beam had already failed, causing large cracks to appear in the cast iron. If the tank did fall, it would destroy the adjacent buildings.

Integral was tasked with rescuing it.



Figure 2 The adjacent buildings provided limited access

Design development

It was immediately apparent that installing support from below the tank would be unsafe. In any case, underground voids would make it

difficult to place new vertical structure on solid ground. What about demolishing, or even carefully dismantling it? This would be no safer and just as costly. Removing the tank also sat uncomfortably with a team and client focused on conservation.

One option remained: could the tank be hung from above? It would be quite straightforward to span new structure over the tank between the walls of the Dye Store, also making the top of the tank accessible. But connecting hangers to the base would be difficult as it contained half a metre of oily sludge and debris. As a bolted cast-iron structure of unknown age, we'd need to take care when applying new forces to it.

Therefore, a two-phase plan was formed: First, the tank would be temporarily hung by its walls only, with the base hanging between in catenary action. This facilitated safe access for cleaning the tank. Second, more tension hangers would be installed to uniformly support the exposed base. With the tank fully supported, the existing structure could be inspected and repaired or replaced.

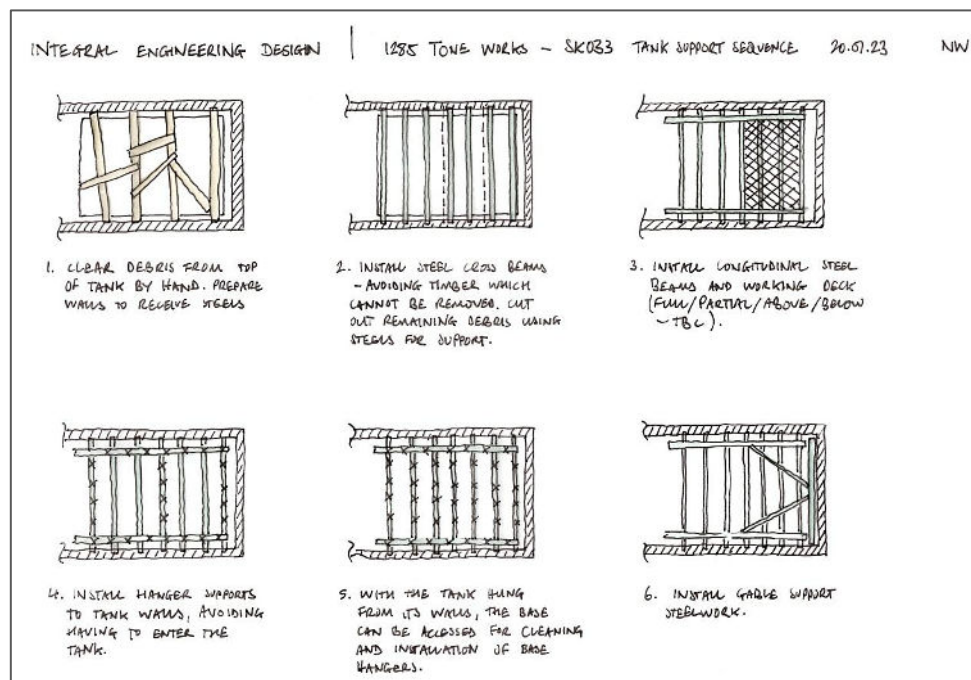


Figure 3 Early sketch of the tank hanging sequence

Detailed design

Seven primary steel beams span over the tank between the existing walls. Secondary beams span perpendicular to these and are aligned with the tank walls below. Sixty-two threaded rods hang from the beams to suspend the tank.

The beam grillage was analysed in Oasys GSA for the hanger point loads of each phase and designed for the worst case. The loads were calculated based on the tributary area of each hanger and our best estimation of the tank's self-weight and imposed loads.

With valuable input from Corbel, a specialist conservation contractor already involved in the wider project, we developed the connection between the hangers and tank walls. A bolted bracket was initially proposed, but the final solution is a steel clamp which utilises a flange at the top of the panels. Unlike a bolted bracket, the clamp could be installed safely and speedily from above the tank, and wouldn't damage the historic fabric by making holes for bolts.

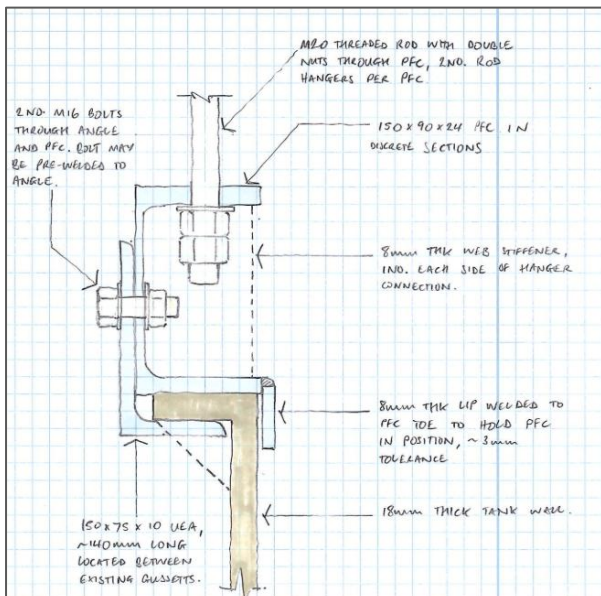


Figure 4 Initial sketch of the clamp arrangement

The clamps comprise a 2m length of PFC bolted to 14 unequal angles, which are used to avoid existing gussets. The PFCs were

limited in length to make them easier to handle and to overcome the slight curvature of the tank walls on plan. The PFCs are designed in bending to transfer the line load from the walls back to a pair of hangers.

When supporting the tank's weight, the clamp would exert a small bending moment on the panel flanges. Knowing cast iron is a brittle material, we were cautious in limiting the bending stress and sought guidance from the *Historical Structural Steelwork Handbook*. An allowable stress of 18N/mm^2 was selected and the clamp was used around the full perimeter, thus spreading the load, to meet this stress limit.



Figure 5 Clamps installed to the tank walls

The next challenge was to get the weight of the tank off the original structure and into the hangers and steel beams. This process was inextricably linked to the hanger design. Crucially, we had to ensure the load was taken up by the hangers and beams correctly. An overloaded hanger could lead to failure of the entire system.

With costs a key consideration, our solution used hand-operated hydraulic jacks combined with load cells. Although strain gauges on every hanger would have provided accurate, real-time load data, they would have been prohibitively expensive. Our chosen method only required two jacks and two load cells to tension one pair of hangers at a time. Some temporary threaded rods and short lengths of

PFC completed the tensioning kits as shown in Figure 6.

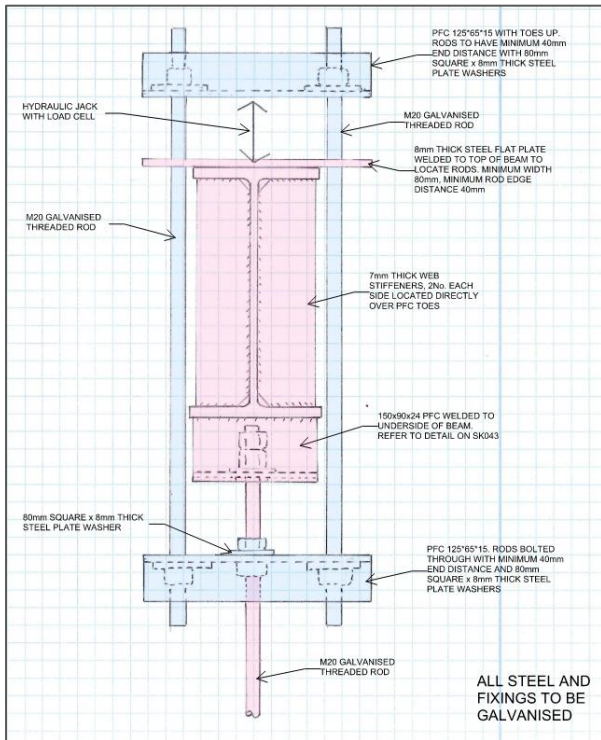


Figure 6 Tensioning kit (blue)

These were moved between hangers in sequence to tension them to 50%, 75%, 90% and 100% load. This incremental loading ensured the whole system was tensioned evenly. At each stage, the nuts connecting the hanger rods to the beams were simply tightened.



Figure 7 Temporary jacking arrangement

Whilst the steelwork was designed for the ultimate limit state, the site team was provided

with the actual unfactored loads to tension the hangers.

The tank was now supported from its walls and could be accessed for cleaning out – a thoroughly unpleasant job by all accounts – and installation of the 24 hangers through the base. These were secured through holes with steel angle spreaders on the underside and tensioned in the same way as the first phase.

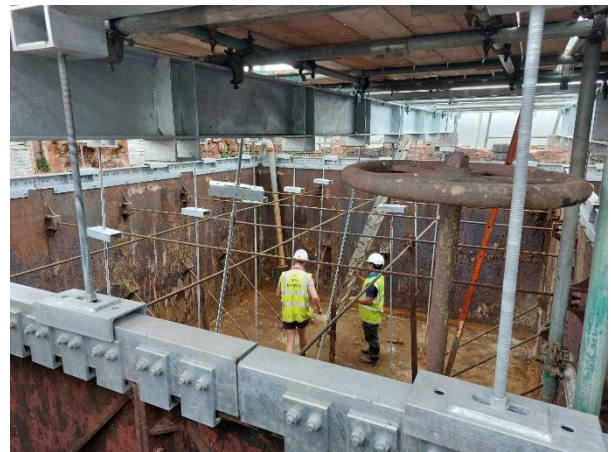


Figure 8 Hangers being installed to the base

Reflection

Inspecting the original structure under the tank soon after, we found several of the columns could be wobbled slightly from side to side, which confirmed they were no longer under load. It was a thrill to realise this cast iron hulk was truly hanging above our heads.

To learn a little about hydraulic jacking and design details which combined the temporary and permanent works was a great challenge. Even more rewarding was to see the designs go from sketch to site in a matter of weeks despite issuing no formal drawings, something only possible with good communication and trust between Integral, Corbel and Western Fabrications, the steel fabricator.

It wasn't a flawless project... during cleaning, a layer of concrete was revealed in the base of the tank, which hadn't been accounted for in the loads. Re-analysis and tightening of assumptions proved there was sufficient capacity, but this brought to light the

importance of making assumptions appropriate for the level of information available, particularly with existing structures.

Despite being technically challenging and under budget and programme pressures, the team's collaborative approach meant these challenges never seemed insurmountable. It

was a joy to work with a contractor in this way, finding solutions together, rather than following a linear design and construction process.

One day, the tank will be re-supported on repaired 19th century beams and columns, and almost no trace of our work will exist.



Figure 9 The completed structure
