Deephams STW

innovative design & construction techniques at one of London's largest STWs lead to significant safety improvements & cost savings

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Located on a vast, though constricted, urban site at Edmonton, Deephams STW provides primary, secondary and tertiary treatment, plus sludge processing, to a population equivalent of 885,000. Demanding treatment of a 14,860 l/s peak flow, the plant services three major sewers entering the works at different levels. Thames Water's £40m reconstruction of the works highlights a range of cutting-edge innovation. This paper details how the collaborative client, consultant and contractor design team has focused on increased operational safety, sustainable building techniques and extensive hydraulic modelling to provide significant capacity improvements to a major sewage treatment works originally constructed during the 1950s and 60s.

The new pump shaft with inlet works behind - Courtesy of J. Murphy & Sons Limited

Existing plant

With the 2 (No.) existing pump stations, 8 (No.) storm tanks and array of screens, grit detritors and settlement tanks largely unchanged since the 1950s, all facilities were in need of a major upgrade. Pump blockages, accumulation of screenings debris and insufficient storm water storage, leads to sewage overspills into local watercourses during storm events.

The area's rising population and expanding commerce, as identified in the London Plan, will equate to an estimated population equivalent of 941,000. Thames Water is planning an upgrade of the effluent treatment streams to cope with this increase and meet new quality standards set by the Environment Agency. The procurement process to appoint a contractor for this proposed major project is nearing completion, with construction scheduled to start in 2015 (subject to planning permission).

Currently however, important improvement works are underway through a £40m design build contract awarded in March 2010 to J. Murphy & Sons Limited, with civils designer AECOM Ltd and M&E supply chain partner Nomenca Ltd. Their primary aims are to improve treated water quality flowing into Salmon's Brook and the River Lea and to increase the plant's storm water storage capacity.

Improvement works

This current contract, due for completion by Autumn 2013, centres on a new pumping station and inlet works for the deepest of the three feeder sewers, the Tottenham Low Level Sewer (TLLS). Routed 18m underground, this 5′ 6″ (1,676mm) diameter double brick sewer, constructed in the early 1950s, regularly surcharges. Its flow has been diverted, while live, into a 50m length of pipe feeding to the new 21m deep concrete shaft housing a total 9 (No.) dry weather and storm flow pumps. From here the 3 (No.) main primary

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REPLACING STEEL IN THAMES WATER'S DEEPHAMS STW

Barchip structural synthetic fibres replacing steel mesh in the Deephams STW project.

The winning project tender bid was supplied by J Murphy & Sons Ltd, with civil designer AECOM Ltd, and M&E supply chain partner, Nomenca Ltd.

A major component of the works was the creation of 2 new 5.6 Million litre storage tanks and modifications to the existing storage tanks to allow sequential filling and draining.

The original slab design for the new tanks (pictured above) as proposed by AECOM had called for traditional steel mesh reinforcement. However, concerns over costs, construction time and durability, as well as health and safety concerns raised by contractors J MURPHY & Sons Ltd caused the design team to look for alternative solutions.

EPC design engineers worked closely with Murphy and AECOM on the flooring design in order to provide solutions to these existing concerns; coming up with a series of finite element analysis (FEA) calculations and modelling to justify their proposals. Using FEA EPC was able to accurately demonstrate the exact location of stresses in the design and provide solutions to ensure the ultimate performance and durability of the structure; especially surrounding concerns relating to the control of crack width openings in the slab so as to ensure leakages would be kept to a minimum.

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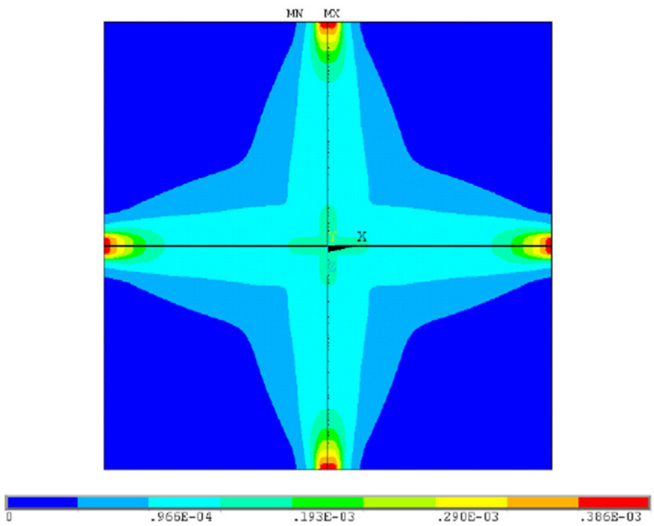
- Highest performing fibre in central load testing
- Flexural toughness equal to steel
- Reduces Costs
- Long term durability - corrosion free
- Increased output and reduced manufacturing costs
- Safer and lighter to handle than steel

Finite Element Analysis modelling from EPC used on the Deephams Project. Modelling shows stresses in the design under specified loads.



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pumps raise up to 1,800l/s to new inlet works where 5 (No.) 6mm fine screens and 2 (No.) grit removal detritors remove rags and smaller solids before the sewage is routed to the existing plant for full treatment.

The 9,500l/s storm flow capacity at Deephams has, for decades, been screened and held back in 8 (No.) 60m long rectangular open concrete tanks until plant capacity is available for it to be treated. The original tanks have now been modified to improve flow and cleaning facilities and two more similar sized tank, 7m deep, have been built alongside to boost storm water capacity by 11,200m^3.

With the new inlets works operational last year, pressure is reduced on the plant's two original pumping stations still serving the other sewers. Known as the High Level and Power House Pumping Stations, their aged equipment is now being upgraded, plus new reception chambers and course screens added.

Pumping station shaft

The contracting team's initial challenge was to construct an 18.5m diameter pump station shaft of sufficient depth to intercept the 18m deep TTLS. Murphy tendered on a diaphragm wall design but, once on site, looked again at the constricted location and the considerable space needed for this technique's handling and bentonite circulation plant.

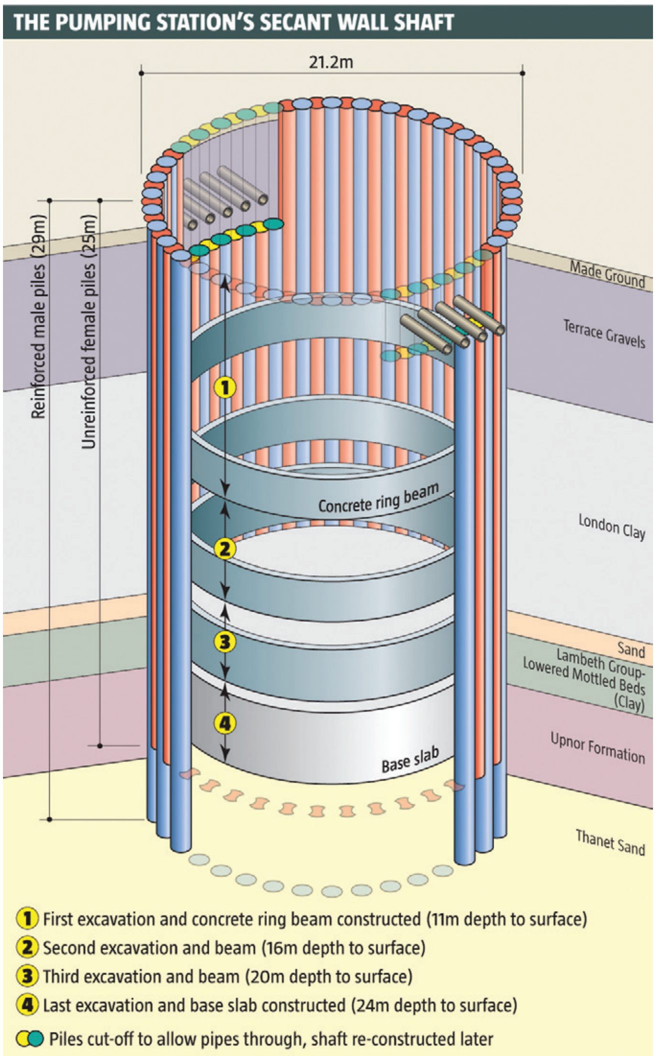
The shaft design changed to the only other option, secant piling. But this required a very deep ring of up to 29m long primary and secondary piles. To create a watertight wall with overlapping piles, the hard secondary piles would have to be drilled into the adjacent softer primary piles over their full depth.

Even though the primary piles would be unreinforced, drill depths to core them out with the secondary piles would need to be considerably greater than the generally accepted 19m UK limit for a secant wall.

Drawing on the experience of Murphy's piling division, plus specialist consultant Byrne Looby Partners, the design team chose to adopt the Irish construction industry practice of an unusual concrete mix for the primary piles offering a 28 day strength of only 10N/mm^2 - half the accepted norm. And to help ensure the onerous 1 in 200 pile verticality required, a surface guide wall was laid to 5mm accuracy with the positions of its 76 (No.) piles set out on a complex double radii grid.

By incorporating the weight of this theoretically 'temporary works' secant wall into the shaft design, overall excavation depths could be reduced by 2m and floatation forces still accommodated. Additionally, 3 (No.) hefty ring beams, required at varying depths within the shaft wall, were formed in concrete rather than steel. This allowed them to later be incorporated into the shaft's permanent internal concrete lining.

Construction of this 600mm thick lining, in full circumferential 3m lifts from the base upward, was achieved without any scaffolding. Instead Murphy brought in 4 (No.) mast-climbing access platforms, normally employed to help clad buildings, and adapted them for circular use. This package of innovative solutions resulted in a watertight shaft constructed successfully within tight tolerances. Its temporary works ended up being 20% cheaper, plus overall shaft construction £300,000 less plus seven weeks quicker, compared to the original diaphragm wall design.



The pump station shaft was formed of the UK's deepest secant piled wall
Courtesy of J. Murphy & Sons Limited

Sewer diversion

Further innovative designs were needed to overcome the high risk challenge of breaking into the constantly live Tottenham Low Level Sewer and diverting its flow into the new pump shaft. The chosen solution involved construction of a 'shaft within a shaft'.

The larger, on line, overhead rectangular access shaft was excavated down to just 2m above the crown of the 60 year old brick-lined sewer. From the floor of this 11.5m rectangular shaft a smaller 4.5m square inner second shaft was dug down around the sewer to its springing level to facilitate break-in and erection of steel bracing protection.

Both shafts were constructed with king post and timber lagging. Vibration was minimised by placing the king posts in pre-augered holes.

The sewer flows at least half full for all but a few late night hours and regularly surcharges, offering a head of up to 5m. The possibility of even emergency overpumping was ruled out as impractical, leaving no alternative but to divert it live.

Risks during the break-in and diversion included sewer damage or even total collapse through vibration or ground heave. This could have resulted in serious flooding of raw sewage in a residential area plus safety concerns for construction employees.

The diversion's year long collaborative planning stage involved discussion with over a dozen separate organisations and stake holders, plus sewer examinations, ground investigations, two-dimensional finite element analysis and installing an elaborate early warning alarm system monitoring flow levels.

A three day low flow window had to be guaranteed for the break-in and installation of a steel flume. This demanded an extensive and fullproof communications network with external Thames Water, local authority and weather forecasting personnel to ensure no possibility of a sudden sewage or surface water surge.

Numerous hold points, during final phases of the six-stage construction operation, were established. But none were needed with no noticeable sewer damage or movement identified during the entire diversion.

Cardboard shutters

To save valuable space within the plant, the new inlet works have been built on circular 400mm diameter columns directly over the two additional storm tanks. To construct this forest of 48 (No.) concrete columns up to 6.5m tall, shuttering formed of 5mm thick cardboard was used.

Simple, sacrificial, cheap and easily stripped, this cardboard formwork proved sustainable and particularly safe to install with minimal need for cranes. By being left loosely in place after initial stripping, it also acted as added protection to the smooth-faced columns.

A vertical wire, running through the full length of shuttering, offered a quick release method. Murphy cast up to 20 (No.) columns a day: four times more than possible with conventional steel formwork.

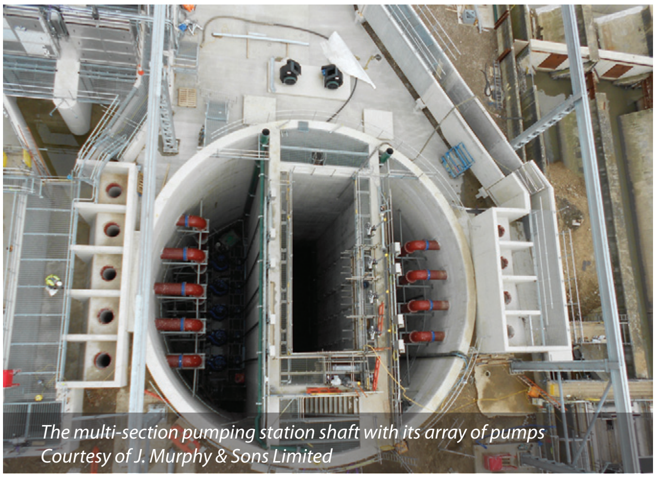
Synthetic fibre reinforced concrete

Construction safety also proved a major catalyst in the choice of material to rebench all 8 (No.) of the existing 1950s storm water tanks. Their required upgrade included a new mixing and suspension system to remove sludge settled on tank floors. But to achieve the required brush-clean finish to tank bottoms during drain down, a strict 1 in 100 fall along the 60m long floor was needed. The old tanks had been constructed to a 1 in 180 slope so had to be rebenched to the new profile.

The inlet works were built over one of the new storm tanks
Courtesy of J. Murphy & Sons Limited

Each of the five storm pumps can fill two bath tubs in a second
Courtesy of J. Murphy & Sons Limited

The confined site led to challenging construction work
Courtesy of J. Murphy & Sons Limited



The multi-section pumping station shaft with its array of pumps
Courtesy of J. Murphy & Sons Limited

The detritors and inlet works remove rag and grit
Courtesy of J. Murphy & Sons Limited

The two new storm tanks increase capacity by 11,200m³
Courtesy of J. Murphy & Sons Limited

A total 2,000m³ of concrete was needed to reprofile all the tanks and, to accommodate long term shrinkage or expansion, anti-crack steel reinforcement mesh would normally have been placed within upper layers of the new benching.

To avoid handling and installing some 80t of steel mesh, Murphy instead opted for a synthetic fibre reinforced concrete. This Elasto Plastic Concrete produced an easily workable mix which, without the possibility of protruding mesh or alternative steel fibres, was both more sustainable and much safer to install. The overall benching upgrade proved two months quicker to complete compared to using mesh reinforced concrete.

Hydraulic modelling

Throughout Deephams' new construction works and existing pumping station refurbishment, physical hydraulic modelling, based on one seventh to one tenth scales, played a major role in design analysis. No more was this evident than in the planning of two new reception chambers to be added into existing inlet works for both pumping stations.

Their primary role was to remove energy from pumped flows upstream of the existing fragile screens and also act as large stone traps. These 10 (No.) fine screens would, in future as historically, remove the smaller solids down to 6mm.

However extensive physical hydraulic modelling of the chambers by specialist Hydrotech Ltd, to analyse benching layouts in sump areas, led to the conclusion that they could be designed to also remove smaller solids. This negated any practical need to continue use of existing inefficient stone traps and their associated confined working spaces.

Similar hydraulic modelling led to design changes in a new air-entrained scour system planned for the pumping station wet wells. Instead a self-cleaning cycle, using existing pumps with suction modifications, was adopted.

The overwhelming advantage of such cutting-edge designs, helped by this extensive hydraulic modelling, is that all Deephams' existing confined space working areas, inside these wet wells and beneath screens and reception chambers, are no longer needed. Man-entry into them for inspection or maintenance is not necessary as the adopted various cleaning and debris removal solutions can all now be serviced from above-ground locations.

The resultant future health and safety of both construction and maintenance crews will be considerably improved.

Conclusions

The already commissioned new inlet works and pumping station facilities at Thames Water's Deephams STW have led to improved quality discharges into the nearby Salmon's Brook and River Lea. This cleaner healthier river water was a primary driver to early completion of this stage of the £40m contract as, some 10km south of the treatment plant, the River Lea flows through East London's 2012 Olympic Games park at Stratford. Here the improved river quality was welcomed by both Games' officials and the park's thousands of daily visitors.

An equally justified welcome should accompany overall project completion by Autumn 2013, when Deephams becomes an even more efficient, economic and safer treatment works. Its refurbishment and upgrade has proved a test bed for innovative collaborative design by client, consultant and contractor, plus sustainable, value engineered construction.

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