Grounds for improvement: Kirkstall Forge redevelopment

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Innovative reinforced earth solutions are at the heart of the redevelopment of one of Britain's oldest industrial sites, in Leeds.

In the 12th Century, the Cistercian monks of Kirkstall Abbey built a millrace to supply water from the Cow Beck to power their corn mill, and in doing s0 gave birth to what is claimed to be the longest continually used industrial site in Britain.

The area subsequently became known for iron production, with the first Kirkstall Forge built in the 1580s. Iron and steel continued to be produced on the site until 2002, when the facility was closed and manufacture moved overseas.

Now, more than a decade after it was closed, developer Commercial Estates Group (CEG) has begun construction on the first phase of a £400M project to breathe new life into Kirkstall Forge, creating 2,400 jobs and delivering a potential £40M boost to the local economy.

Temporary sheet pile walls were installed to allow excavation of made ground before construction of the new river banks

When complete, the 23ha site will become a thriving mixed-use community of 1,050 homes, 300,000 ft^2 of commercial offices, along with cafes, restaurants, retail and leisure facilities. It will be served by a new railway station linking it in minutes with Leeds city centre. The historic forge will become a focus for the public realm.

Construction of the first phase began in October 2014, with main contractor I&H Brown carrying out earthworks and constructing initial infrastructure. Construction of the first 110,000 ft^2 of commercial office space and 240 apartments, plus the new railway station will follow under separate contracts. Civil engineering and environmental consultancy for this phase is being provided by Leeds City Council and WYG.

“A key element of the project is construction of a road between the A65 Abbey Road running along the site’s northern boundary and the new station to the south, which entails crossing the River Aire bisecting the site,” explains I&H Brown project manager Steve Cooke.

“The site is in the bottom of the river valley,” he adds, “and the A65 is about 15m higher than the river, so we are having to raise ground level between the ‘Stitch Bridge’ and the main road to create a suitable road gradient.

The bridge’s bank seats sit directly on the reinforced concrete

“The underside of the bridge deck also has to be 600mm above the 1 in 100 year flood level. All of this means we have to raise the height of the northern river bank and reinforce the southern one, to accommodate the 30m long, 18m wide span.”

WYG associate Rebecca Reynolds explains that one of the original options was to use reinforced earth walls to accommodate the new crossing. “However, sheet piles were chosen, to create an industrial look to match the site heritage,” she says. “During the early design stages, it became clear that driving and anchoring the sheet piles would be time-consuming and expensive, so it was decided to revert to a reinforced earth solution.”

The design involves replacing 210m of the northern river bank and 125m of the southern bank with new slopes, constructed from imported and site won granular fill reinforced with multiple layers of Huesker UK’s high strength polyester Fortrac geogrids.

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>
> WYG associate Rebecca Reynolds

The northern bank is being raised a further 5m by placing more layers of reinforced granular fill on top of the slope, with an Allan Block segmental block retaining wall, again reinforced with Fortrac geogrids.

The bridge is founded on concrete bank seats built directly on the new reinforced earth structures.

One of the challenges was to satisfy Leeds City Council’s bridges and structures team that building a bridge with a 120 year design life on a reinforced soil slope would be acceptable. Huesker presented similar projects across Europe to demonstrate the solution’s success and, along with Allan Block, introduced a “positive connection” between the geogrid and the wall, giving added strength to the structure.

The new northern river bank comprises a 5m high Allan Block retaining wall sitting on a reinforced soil slope to provide foundations for the new road bridge

“Previously, this connection would just have been provided by the friction between the blocks,” explains Huesker UK managing director Graham Horgan. “Now the geogrid wraps around positive connection bars sitting in recesses on the top of the blocks, giving higher connection strengths and allowing more flexibility in the geogrid spacing and layout.”

Detailed design of the slopes and wall was carried out by I&H Brown’s specialist installer Thomas Ben and its reinforced earth consultant PaSCoE.

The 37° to 60° reinforced soil slopes include up to 16 layers of Fortrac geogrid, placed on 400mm thick layers of compacted granular fill. Three types of Fortrac are being used, with ultimate tensile strengths of 55kN/m (Fortrac 55T), 80kN/m (80T) and 110kN/m (110T), anchored up to 12m into the slopes, depending on their height, which varies along the river to a maximum of 6.2m.

The slope face is formed by wrapping the geogrid around and back on itself, behind which topsoil and a green mesh is placed, creating a natural looking river bank.

The Allan Block wall also uses combinations of Fortrac 80T and 110T geogrid, laid at 200mm and 400mm centres, with anchor lengths of 7m. The bridge's bank seats sit on nine layers of Fortrac 110T, with anchor lengths of 10m. The near vertical Allan Block walls are formed of concrete blocks sitting on a levelling strip of C32/40 concrete and are founded directly on the reinforced slope. Finally, a hardwood parapet will be built on top.

An added complication for the designers was the requirement for a cantilevered pedestrian platform along part of the north river wall.

The geogrid reinforcing the soil wraps around bars in the Allan Block wall to giving added strength to the structure.

"We believe this is the first time in the UK that a cantilevered structure has been founded directly in a reinforced earth wall," Reynolds says. "The walkway will be supported on a series of steel beams, partially encased in concrete, which pass through the reinforced soil and will be supported by a mass concrete foundation, to counterbalance the load on the platform."

Ground conditions

Ground conditions at the river comprise up to 5m of made ground – mainly demolition material, plus ash and clinker from the forge – over alluvial sand and silt and river terrace gravels, with weak mudstones and siltstones at about 12m depth.

"The new reinforced earth slopes are founded in the river terrace gravels," says Cooke. "So we had to design and install temporary sheet pile walls to allow us to excavate in the dry." The 200m long northern wall and the 125m long southern wall were formed using 10.5m long AZ19-700 sheet piles.

The northern reinforced soil slope and bridge bank seat were finished in July, with the Allan Block Wall reaching the cantilever beam foundation level.

"On the northern bank, groundwater is discharged through silt traps into the river, with the approval of the Environment Agency," says Reynolds.

The bridge beams arrived on site in early July and are due to be lifted into position in mid-August, so the team is still on target to complete the road in time for the opening of the new Kirkstall Forge station later this year.