Faithful retainer

Diaphragm walling is an established technique for basement construction. David Puller and Nick Wharmby examine its development and the advantages it brings.

When oil industry technology was transferred to applied civil engineering in the 1940s it opened the way to the use of slurry-supported excavations in construction of earth and water retaining structures.

The technology was developed by Italian companies building cut-off dams in the 1950s and was first used in the UK in 1962 at London's Hyde Park Corner. Now, after 50 years, the technique can be considered a mature and well-understood process.

It did not take engineers long to realise the design advantages of these slurry-supported, rectangular elements over walls formed from interlocking, cased bored piles. Soon embedded walls were being built with T-shape panels, castellated and cellular walls, precast and even prestressed diaphragm walls.

Increased structural efficiency was being achieved with an associated reduction in other forms of temporary and permanent earth support such as props and tiebacks.

In water-bearing ground the reduced number of wall joints compared with a bored pile wall is considered advantageous with regard to potential water ingress. Nevertheless, a potential water path still exists between panels and the incorporation of a continuous water bar system is recommended. CWS is such a system which also provides guidance to the grab excavation.

Connections to retaining walls are more readily achieved where diaphragm walling is adopted when compared with piled walls; box-out, pull-out bars and couplers can be incorporated into the cage and relatively accurately positioned. This can be particularly advantageous in cases of top-down construction.

The resulting finished diaphragm wall surface can, under certain circumstances, be acceptable, with limited treatment, as the final internal surface. This is often the case in cut and cover tunnel and metro station boxes or even underground car parking structures. The construction of precast diaphragm walls can provide an even better surface finish if required.

Development

Progress has nearly always been led by plant manufacturers with the development first of cable operated and hydraulic grabs able to dig dense and stiff soils.

In the 1970s, hydrofraise technology made possible excavation rates of up to 400m² in a single shift, unheard of in very dense granular strata and weak rocks.

Bentonite treatment plant technology was developed to handle the associated increased throughput, as slurry was used not only to support the excavation but also as a spoil transportation medium.

Improvements in mud seals, verticality control devices and instrumentation pushed back the limits. Panel depths of more than 100m became achievable, together with improved dimensional accuracy of up to 1 in 500 with the hydrofraise.

Reduced height cutter frames resulted in compact equipment that made excavation in limited headroom feasible. Wall thickness of 1,500mm and even 1,800mm also became possible.

Most recently, the attachment of rock roller bits to conventional cutting wheels has enabled cost-effective excavation of hard rock with a uniaxial compressive strengths of over 150MPa.

CWS diaphragm wall panel joint system.

Exposed diaphragm walls can often form the final internal finish of underground structures.

Hydrofraise diaphragm wall construction can be fast, even in difficult ground.

Logistics and environmental constraints

Many practical issues can impact heavily on the design of diaphragm walls and seeking the advice of a specialist contractor is strongly advocated.

The panel layout is fundamental to the whole process as it influences wall alignment, panel stability, bentonite storage capacity, construction sequence, reinforcement cage detailing, cage fabrication area, handling crane size, productivity and thus cost. In normal circumstances panel lengths of between 6m and 7m are adopted for technical and productivity reasons.

The shape in plan of the proposed bulk excavation can influence the cost-effectiveness and practicality of the system. As most digging tools excavate a 2.8m length of wall in a single "bite", a panel is made up of multiple "bites" with an overlap.

Bentonite storage and management is essential to maintain productivity levels. Storage volumes need to be about four times the volume of a panel; this can be provided by lagoons or tanks.

Bentonite conditioning is an ongoing process. It should be noted that where a hydrofraise is used the cleaning plant must be able to adequately clean 450m³ per hour per hydrofraise, as the spoil is carried in suspension within the bentonite drilling fluid.

In this case the mud handling requirements are far more demanding than when digging with a grab, especially in fine sands and silts.

Without exception, specialist contractors will detail or re-detail reinforcement cages to suit stopends, tremie pipe locations, lifting preferences and so on. They will also decide whether the cages are lifted in one section or jointed over the trench.

On small sites, cages can be manufactured off site and transported to site as required. In extreme cases, cages can be coupled over the trench during installation, but a trial assembly must be completed first, as part of the fabrication process.

As with piles cast under bentonite, overly congested steel with a clear spacing between bars of less than 100mm will compromise concrete quality. Similarly poorly designed box-outs will result in localised poor quality concrete.

The way forward

Advances in plant technology have opened the door to the widespread use of diaphragm walls in challenging ground conditions.

As a result, the design process is heavily interlinked with construction practicalities; this is perhaps more true than with conventional piling. The early involvement of practitioners in the development of design concepts is therefore essential.

Finally, it is worthwhile considering the procurement culture for basements. Although this is changing, traditionally the retaining wall has been seen as an element of the basement works, with specialist contractors submitting tenders for the piled or diaphragm wall "element" only. This has lead to a cheapest-element-wins culture rather than optimum overall basement cost.

Early input from a specialist contractor will lead to the best overall solution in terms of not only the embedded wall but the temporary and permanent propping, construction sequence, panel layout and construction details such as water-proofing.

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