Temporary Works Toolkit

Part 8: Use of modular hydraulic propping systems for the temporary support of deep excavations

The Temporary Works Toolkit is a series of articles aimed primarily at assisting the permanent works designer with temporary works issues. Buildability – sometimes referred to now as 'construction method engineering' – is not a new concept and one always recognised as vital to the realisation of one's ideas; it ought to be at the forefront of an engineer's mind.

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Introduction

Temporary works design is often perceived as the poor relation to permanent works design with, by definition, little or no evidence of its presence in the completed project. However, well-designed and, of course, well-executed temporary works solutions can lead to big cost savings, while providing a safe and efficient environment for the permanent works to be built. This is particularly the case with below-ground temporary works, where there are a great many challenges to be faced by a temporary works designer, who is often working right 'at the end of the food chain' of information flow. Soil mechanics, whether it is for a shallow trench or a deep basement, is an inexact science at best, relying heavily on engineering judgment to provide a safe, economic and practical solution.

Nowadays in the UK, the majority of below-ground temporary works support is undertaken using proprietary equipment, provided on a rental basis by specialist suppliers. Over the last 30 years, the scope of proprietary equipment has increased dramatically. In the 1980s, proprietary equipment was limited to shoring up pipe trenches and small-scale pits, which were supported with hydraulically operated aluminium waler frames or the ubiquitous manhole brace. Today, there is a huge range of equipment available to support all sizes of trench, shaft and cofferdam. It is not uncommon to see modular hydraulic struts (Figure 1) clear-spanning over 40m.

Proprietary vs timber vs fabricated steel

Both site-fabricated welded steel and good old timber continue to be used as a means of support. These traditional shoring techniques tend to be favoured by piling contractors and specialist utility contractors respectively, who often hold stocks of the appropriate materials and have the necessary trained personnel to construct, fabricate and weld on site.

There are two main advantages of proprietary systems: firstly, they allow simple and rapid installation requiring little, or in most cases, no welding on site; and secondly, the modular systems are reusable and offer huge advantages in terms of sustainability and overall value. Healthy competition between suppliers ensures that rental rates remain competitive. In addition, the major suppliers of these systems offer in-house complimentary design and advisory services, backed up by site support personnel who provide advice and training where it is needed. This ensures that this type of equipment is designed and used safely and effectively.

Market scope

The UK proprietary shoring rental market is huge, probably in excess of £100M per annum. Outside the UK it is a different matter. Within mainland Europe, proprietary shoring is generally limited to trench box and slide rail systems for linear trench support, with Germany in particular having a number of large manufacturers of this type of equipment. Larger cofferdams and basements, however, are still typically supported with traditional fabricated steel frames. Where conditions permit, ground anchors are a favoured means of support. Their obvious advantage is that they do not intrude into the excavation. The same situation holds true in the Middle East, where ground conditions (predominantly rock) and availability of space makes tying back with anchors the favoured solution. North America and Australia have similar shoring practices to the UK, having established markets for the full range of proprietary systems.

Recent developments in proprietary equipment have seen the introduction of integrated load-monitoring systems within struts. These predominantly wireless systems offer a huge improvement over traditional wired strain gauges attached to the strut surface. The use of modern technology allows the site team 24/7, real-time access to load data through the internet and mobile devices.

Modern proprietary shoring products are most accurately considered as systems rather than individual structural components. The concept behind all modern-day systems is the replacement of one-off fabricated shoring or bracing with a multi-use solution.

Figure 1
Temporary propping of deep excavation using modular hydraulic struts

As stated earlier, the key to the success of proprietary equipment is its speed and ease of use, and its reusability.

These two attributes combine to make the equipment a realistic hire item on a commercial basis. While the boundaries for proprietary systems are constantly expanding, it is clear that there is an ultimate size limitation for modular proprietary equipment. Its increase in size, and hence specialisation, tends to be disproportionate to its utilisation and commercial viability from both the supplier's and user's perspectives. Other factors that inhibit growth are: ultimate weight; associated transport and handling problems; and the cost associated with longer-term hire periods.

Notwithstanding these limitations, the use of proprietary equipment for the support of basement excavations has seen a steady increase in popularity in the UK and, more recently, in Europe and the USA. This has prompted the development of very heavy-duty equipment. Struts are now available that can provide up to 5000kN of resistance while spanning distances approaching 50m.

Rental vs purchase

One of the more frequently asked questions is whether it is cheaper in the long term to rent or to purchase proprietary shoring products. The single factor that will determine this is project duration. Most suppliers require significant capital investment in their modular systems so that they can establish a vast fleet of stock, capable of accommodating endless configurations of equipment. Therefore, unless an individual project duration is excessively long, it is highly unlikely that purchase of the equipment will be viable. Rental suppliers, operating in a highly competitive market, are generally keen to use innovative pricing mechanisms to tip the balance in favour of rental. Indeed, we have seen rental durations of two years prove to be economic. One market sector that bucks this trend is the burial business. Clearly, the regular and consistent excavation size associated with grave excavations favours the purchase of proprietary 'grave shoring' products!

Technical challenges

As the size and complexity of proprietary systems increases, so do the design challenges faced by supply chain temporary works engineers when specifying these systems. Theirs is a constant dilemma; first and foremost, structural adequacy and safety is paramount. This, put simply, is the task of balancing forces and resistances while leaving a margin for safety. However, the supply chain mantra of 'no win, no revenue' dictates a need for commercial acceptance. Over-designing and incorporating large, comforting factors of safety is not really an option for 'commercial' designers operating in a cut-throat, highly competitive industry.

The introduction of the structural Eurocodes, which are now mandatory on capital schemes, has added more complexity to the design process. Temporary works engineers in the UK have generally been reluctant to adapt to the limit state processes, particularly in relation to Eurocode 7 (geotechnical design)[1,2], with it requiring a radically different approach to previous 'working load' methodology. This is certainly the case in relation to smaller-scale excavation support, where Eurocode design is considered in the same regard that a sledge hammer is to crack a nut. Indeed, the latest British Standards Institution documentation, such as PAS 8812 (application of European Standards in temporary design)[3], continues to refer to 'safe working load' non-limit state methodology.

So, for the foreseeable future at least, it remains current practice in the UK on anything other than a major project to design in accordance with 'safe working' or allowable load methodology; equating un-factored calculated loads, based on moderately conservative ground parameters, to allowable

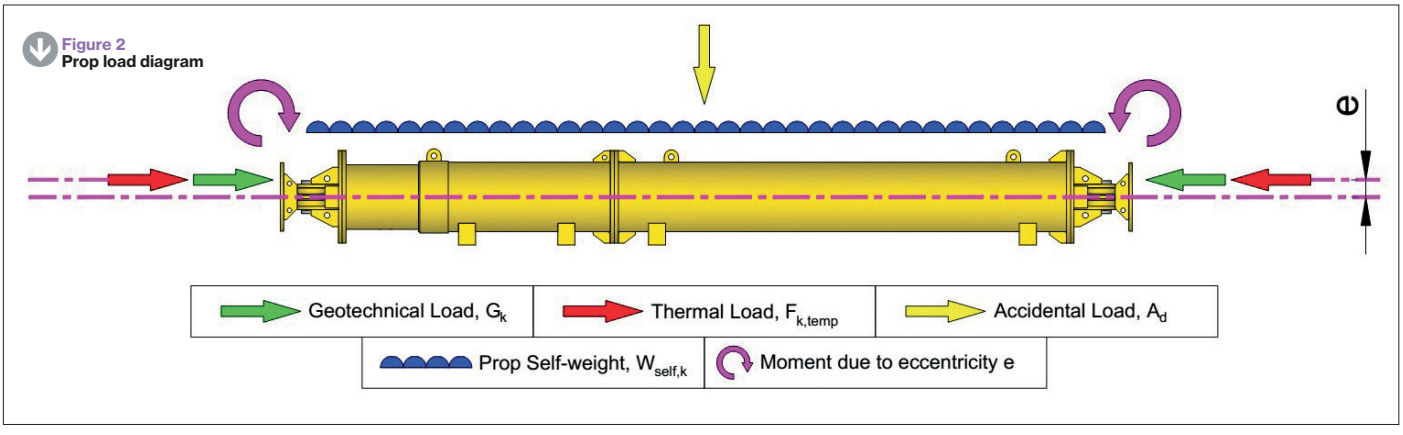

Figure 2
Prop load diagram

Figure 3
Integrated connection between prop and reinforced concrete capping beam

or 'safe' factored resistances that incorporate a 'lumped' factor of safety. Working values for equipment quoted in suppliers' load data charts tend to be determined by reducing ultimate resistance values by a single factor, typically between 1.5 and 2 for temporary works equipment.

Designing to structural Eurocodes

With the relatively recent introduction of the suite of structural Eurocodes into the UK and the consequent replacement of the traditional British design standards, loads or, more correctly, actions on support systems will need to be calculated and presented in terms of limit state design values incorporating partial factors specified within national annexes. These **design actions** will need to be equated to limit state **design resistance** values for the equipment being specified.

It is important, therefore, in the transition period between allowable and limit state philosophy, to fully understand the various design terms to ensure that load factors are applied correctly; thus ensuring that equipment is specified within its capacity.

Thermal load considerations when designing long-span props

Loading induced by ambient temperature fluctuations can have a large effect on the load in long props and can represent a significant proportion of the design loading. It is essential that thermal loading is considered in combination with the other loads likely to be imposed on a prop (Figure 2).

Recent advances in load monitoring technology have enabled the performance of braced excavations to be analysed with a better degree of accuracy and reliability. This information can be of use to engineers in a number of ways, such as to compare the predicted and actual performance of support systems and to adopt observational methodology with a greater degree of confidence.

Practical matters

As mentioned earlier, the main advantages with any proprietary system are: availability of equipment; specialist design service; as well as the speed and convenience of installation and removal on site. With shoring systems this is no exception. Although, as the equipment gets bigger, the installation methodology gets more complicated, particularly on major projects where temporary works is linked more closely with the permanent works construction. Far more detailed planning is required on these projects to avoid costly delays and potential clashes. Larger equipment also puts far more demand on cranage and logistics in general. This has to be scheduled in with the construction of the permanent works.

Complex excavation footprints such as that shown in Fig. 1 will require careful design attention to deal with shear, uplift and lateral forces created by non-perpendicular struts, such as knee braces and raking props. Integrated connections, as illustrated in Figure 3, cast into capping beams can simplify connection details between the props and the wall significantly; as opposed to relying on bolted shear connections requiring vast amounts of post-fixed bolts once the beam has been cast. The former arrangement requires forethought and planning, emphasising the need for early involvement between all parties.

All too often, fundamental decisions on what type of system is to be used and who is supplying it are made at the last minute, which can have significant implications on the success of the project. Connections between struts and capping beams are just one example of how early design cooperation can be of benefit, both in terms of cost and safety.

Digital revolution – BIM

While on the theme of planning and clash detection, three-dimensional (3D) modelling across a shared digital platform, broadcast under the banner of Building Information Modelling (BIM), is currently revolutionising the industry. BIM, often thought of as being limited to permanent works, is becoming firmly entrenched further down the supply chain. It is an ideal platform for incorporating temporary works propping and framing, for example, thus ensuring clash detection is a straightforward process. Currently, there is a huge investment in technology across the supply chain in order to meet the demands of BIM. In the UK, BIM is already mandatory on government-funded projects and more clients are sure to follow this approach.

Summary

To get the best out of proprietary systems, it is essential that the specialist equipment designers get involved in both the permanent and temporary works design process early, as is often possible, with the vast range of off-the-shelf equipment that is available in the market place, to offer innovative solutions, requiring less propping and far greater convenience to the construction process.

REFERENCES

►1) British Standards Institution (2004) *BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design. General rules,* London: BSI

►2) British Standards Institution (2007) *BS EN 1997-2:2007 Eurocode 7. Geotechnical design. Ground investigation and testing,* London: BSI

►3) British Standards Institution (2016) *PAS 8812:2016 Temporary works. Application of European Standards in design. Guide,* London: BSI

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