Temporary Works Toolkit

Part 3: Integration of permanent and temporary works

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 is waste. There, I said it. As a practising temporary works designer, this is an awkward truth. Temporary works are essential to the construction process, but at the end of the day they will be removed and there will be nothing to show for them. Therefore, anything that can be done to eliminate or simplify temporary works has to be a good thing.

Temporary works can also be costly. Focusing on the simplest looking permanent works scheme might not produce the cheapest scheme overall once the cost of the temporary works has been taken into account.

The permanent works designer (PWD) has a major influence on the temporary works and can, for example:

- eliminate temporary works, e.g. through the use of steel decking rather than timber falsework
- minimise the use of temporary works, e.g. by using the permanent capping beam as a waling in basement construction
- design the permanent works so that simple temporary works solutions can be used

This article will look at three examples in more detail, including of permanent works in the temporary condition; in each case, references for further reading are given.

Using suspended slab as support to falsework

In multistorey, reinforced-concrete (RC)-framed structures, it is necessary to support the suspended floor slabs from the floor below during construction. A 300mm thick slab has a weight of 7.5kPa and there are additional loads from the falsework (usually taken as 0.5kPa) and live load (1.5kPa), resulting in a total characteristic load of 9.5kPa. This load has to be carried by the floors below and most floor slabs in buildings are not designed for superimposed loads of this magnitude. Where this is the case, the floor can be backpropped to the floor below (Figure 1).

When constructing RC slabs, full-scale tests[1] have shown that two levels of backpropping can be effective, but at least 50% of the load from the slab is carried by the slab immediately below the slab being constructed, and as little as 30% is carried by any backpropping. Therefore, every slab has to be able to carry a live load equivalent to at least 50% of the construction load of the slab above, which would be a characteristic load of 4.75kPa in this example. A further consideration is that the contractor will not want to wait for the slab to gain this strength before casting the slab above, so the slab must be capable of carrying this load at an early age. The contractor might want to use concrete with a higher characteristic strength so that the required strength is reached after a few days rather than a few weeks.

Two levels of backpropping takes time to install and remove, but its main disadvantages are the delay to following trades and the sterilisation of the slabs as storage areas; if the strength of the slabs is being used for backpropping, it is not available for the storage of materials.

This is a gross simplification of the backpropping process (which will be discussed in more detail later in the series; for the full process, see Pallett[1]), but it illustrates how the PWD can simplify the construction process by designing slabs for these construction loads. Often, a small increase in the amount of reinforcement would eliminate the need for backpropping and speed up construction, saving the client money overall.

Profiled-steel permanent falsework (steel decking)

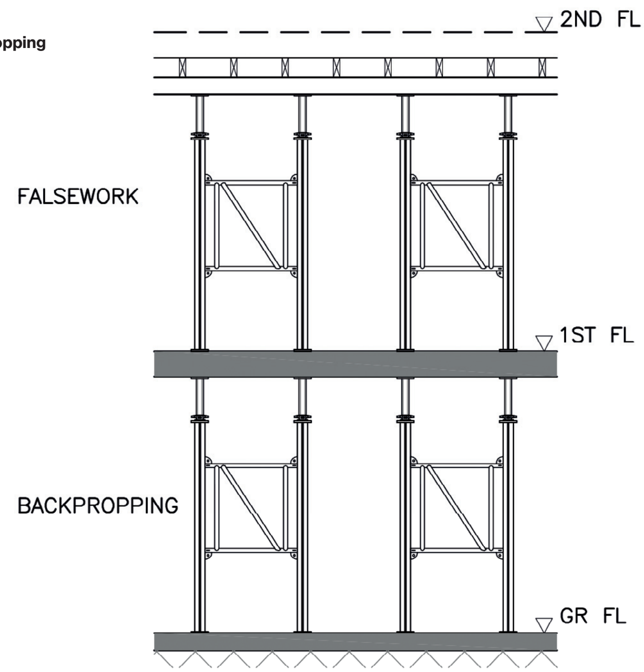
It is now standard practice that the floor slabs in steel-framed buildings are designed and constructed using profiled-steel permanent formwork (also known as steel decking[2] or metal decking[3]). The decking is usually designed compositely with the steel frame and has several advantages over propped falsework: it minimises the need to work at height; the absence of propping allows following trades to progress; and it saves the time of erecting and removing falsework.

It is usual for the designer to leave the specification of the steel formwork to the contractor, who can then get quotations from several suppliers and select the best price. The suppliers look at the permanent works drawings and work out the best layout for their products, assuming that the beams supporting the permanent formwork have zero deflection. Typically, a length of decking of two or three spans will be specified by the supplier. Sometimes the supplier will specify the location of props to support the centre of a panel, particularly on long spans. Typically, the supplier will state in the small print of the quotation that the formwork has been specified on the basis of rigid supports, and typically the contractor will only install props where specified by the supplier.

Here, there is a potential problem with a disjoint between the design assumption of rigid supports and the actual situation of a flexible steel frame. Settlements of 60mm under the steel frame are not uncommon (Figure 2) and the implications of this are that:

- the permanent formwork could be excessively loaded, e.g. a slab with a nominal thickness of 130mm could be 190mm thick – an increase of nearly 50%
- concrete usage is about 20% greater than budgeted
- the unknown position of the joints in the decking means an unknown distribution of dead load in the structure due to continuity of the decking over an unknown number of spans
- an increased dead load is imposed on the steel frame and foundations
- an increased stress is induced in the steel beams before composite action is achieved – possibly close to the permissible stress even before live load is applied
- deflection of the steel beams becomes a permanent feature of the structure, limiting the space available for services

Figure 1 Backpropping



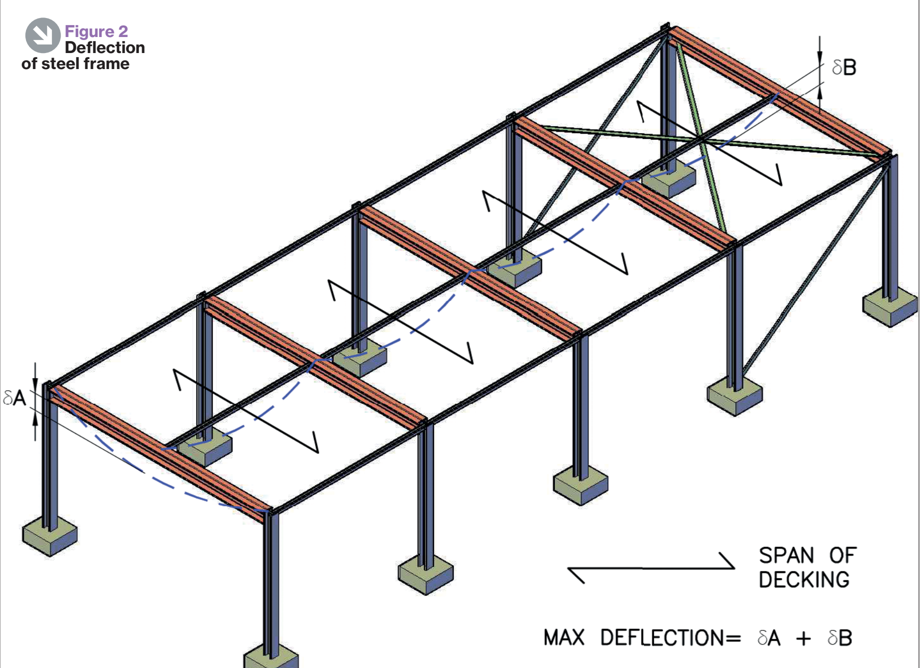
The advantages of the use of permanent formwork outweigh the potential disadvantages, but care is needed to ensure that the implications listed here do not become an issue during construction or use of the structure, and this starts with the PWD. One way of doing this is for the PWD to specify that the steel beams must be propped during concrete placing. However, this negates some of the advantages of using steel decking and would delay construction, leading to increased costs for the contractor and ultimately the client.

An alternative is for the PWD to make some assumptions on the layout of decking to be used and to show this on one of the construction drawings (Figure 3). When doing this, the PWD should also bear in mind that decking over two or more spans is safer and less likely to require propping than decking over one span[3].

Another consideration should be manual handling[4–8]: the decking can be craned close to its point of use but it has to be manually lifted into position.

Different types of decking have different load capacities and weights so the PWD should have some idea of suitable products when drawing up the layout. This layout can then be used to calculate deflection of the steel beams when concrete is placed, so that the distribution of dead load within the structure is known and the building can be designed accordingly. Potential deflections can be shown on the drawings so that the supplier of the steel decking can add them to the nominal thickness of the slab when specifying the steel decking.

Figure 2 Deflection of steel frame



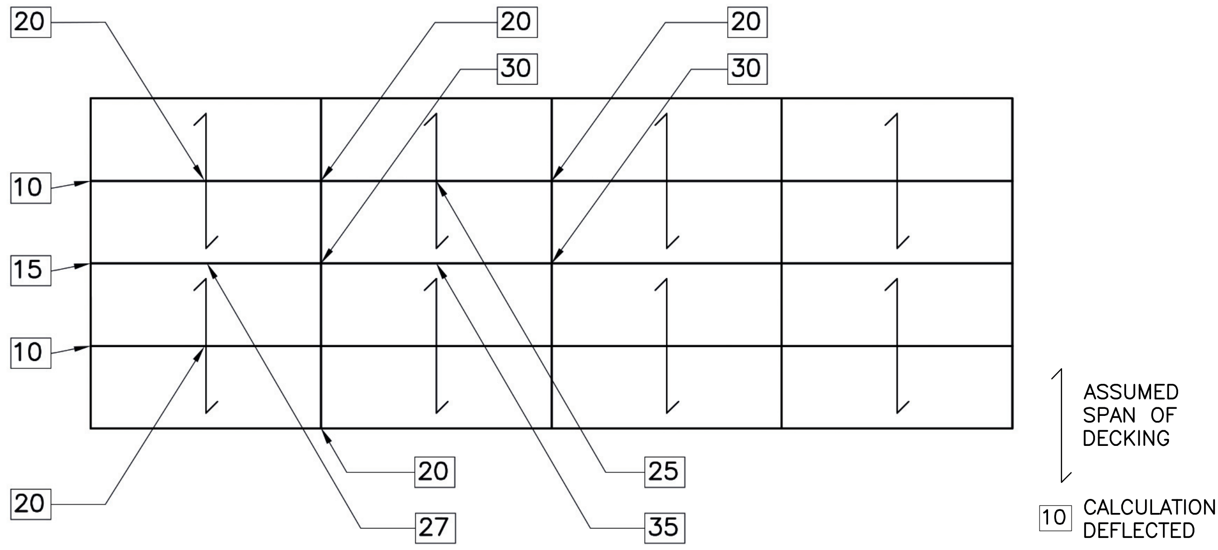


Figure 3 Permanent works drawings showing assumed span of sheets and calculated deflections

Retaining walls

When selecting the form of a retaining wall, the PWD must consider how the wall will be constructed. For example, where a retaining wall is required on the site boundary, some form of temporary retaining wall would be required to construct an RC wall. By recognising this, the PWD can design one wall that will do both jobs. This is likely to be an embedded wall: either sheet piles or a secant/contiguous pile wall. On deeper basements, it is not usually possible to cantilever the piles in the temporary situation so some form of propping is required[9]. The PWD can further simplify construction by designing the permanent works for the temporary load cases. For example, the capping beam can be designed as a waling to eliminate the need for a temporary steel waling. Often, this will only require a relatively small amount of additional reinforcement to deal with the temporary situation.

It is important that the PWD makes clear their assumptions about the construction sequence. This will show the contractor one method of constructing the works, but also alert the contractor that any alternative method might have an effect on the design of the permanent works.

The contractor will probably want to reposition the props from any position assumed by the PWD, so a robust design with a constant level of reinforcement will maximise the options for prop positions. Usually, once the contractor has been appointed, there will be several months before the capping beam has to be installed and the beam can therefore be designed once only for the specific prop layout proposed by the contractor.

The piles themselves are often contractor-designed elements, so they can be designed for the temporary prop levels required by the contractor. Where an intermediate level of props is required between the basement slab and the capping beam, it is beneficial if these can be positioned just above the top of the intermediate slab (Figure 4). This avoids:

- having to construct walls around the props and walings
- falsework around the props
- having to remove props once the slab above has been constructed

A level of props takes time to install and remove, so if it can be eliminated, at a cost of additional reinforcement in the piles, then the saving in on-site costs will usually be worthwhile.

Summary

Temporary works can be expensive, time-consuming to install and remove, and can be considered waste. Therefore, it makes sense to reduce the amount and complexity of the temporary works. Examples have been given of places where the PWD can eliminate, reduce or minimise the extent of the temporary works required, but the list of such situations is endless. For all designs the PWD should consider temporary works and constructability and should try to simplify the overall construction process. The cost of the time spent by the PWD will be more than offset by the time and cost savings on site.

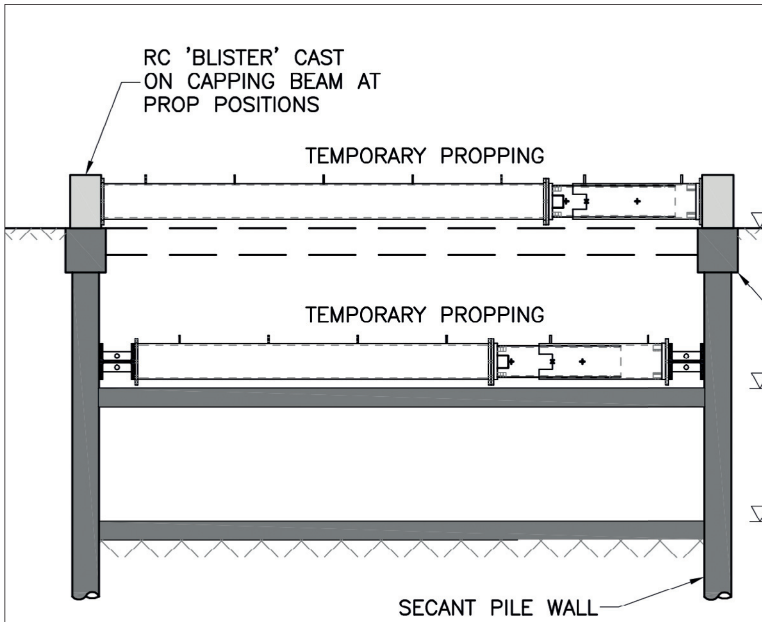


Figure 4 Propping to basement

References

1. Pallet P. (2003) *Guide to flat slab formwork and falsework*, Crowthorne, UK: Concrete Society

2. Rackham J.W., Couchman G.H. and Hicks S.J. (2009) *Composite slabs and beams using steel decking: best practice for design and construction* (MCRMA Technical Paper No. 13; SCI Publication No. P300), Prenton, UK: Metal Cladding and Roofing Manufacturers Association and Steel Construction Institute

3. British Constructional Steel Association (2004) *BCSA Code of Practice for Metal Decking and Stud Welding*, London, UK: BCSA

4. British Constructional Steel Association (2010) *SIG.01: Manual handling survey* [Online] Available at: www.steelconstruction.info/File:BCSA_SIG-01.pdf (Accessed: October 2016)

5. British Constructional Steel Association (2010) *SIG.02: Off site cutting procedures – case study* [Online] Available at: www.steelconstruction.info/File:BCSA_SIG-02.pdf?internal_link (Accessed: October 2016)

6. British Constructional Steel Association (2010) *SIG.03: Material loading out and positioning guidelines for principal / sub-contractors* [Online] Available at: www.steelconstruction.info/File:BCSA_SIG-03.pdf (Accessed: October 2016)

7. British Constructional Steel Association (2010) *SIG.04: Manual handling – advice to structural engineers* [Online] Available at: www.steelconstruction.info/File:BCSA_SIG-04.pdf (Accessed: October 2016)

8. British Constructional Steel Association (2010) *SIG.05: Manual handling of decking sheets - reducing the handling risk* [Online] Available at: www.steelconstruction.info/File:BCSA_SIG-05.pdf (Accessed: October 2016)

9. Gaba A.R., Simpson B., Powrie W. and Beadman D.R. (2003) *Embedded retaining walls – guidance for economic design* (CIRIA Report C580), London, UK: Construction Industry Research and Information Association