Early age construction loading

Figure 1: Backpropping installed at St George Wharf

Early age construction loading can be the most significant load experienced by multi-storey structures.

Key points

This Case Study looks at the experiences of applying new criteria for the striking of slabs and the design of backpropping.

- In residential developments the spare load bearing capacity of slabs used in determining backpropping requirements is very low because of the low level of imposed load specified. This is important because such spare capacity needs to be available to support freshly cast concrete.
- It was found in practice that the levels of preload measured in individual backprops were high.
- When the effect of preload was taken into account, the distribution of loads for the supporting slabs was found to be close to that predicted by conventional approaches assuming an even distribution of load between slabs.
- Quality control concerning the type, positioning, sequencing of placement and removal and tightening of backprops is important and does not always appear to be exercised.
- The temporary works designer and permanent works designer should work together to assess whether a higher design load should be used to cater for the construction load conditions.
Criteria for early age loading
Work carried out on the in-situ concrete building at Cardington highlighted the potential benefits that could be achieved by adopting revised criteria for striking and the design of backpropping based on serviceability. This led to the preparation of a Best Practice guide, Early striking and improved backpropping for efficient flat slab construction.

Findings in relation to striking
The expectation was that adopting the new criteria would allow striking at lower concrete strengths than currently permitted. However this was found to be very much depend on the assumptions made. As fairly optimistic assumptions were used for the existing criteria, it was not considered prudent to revise the existing criteria, it was not always appear to be exercised at St George Wharf in accordance with the calculations presented. Because of the possibility of significant preload being introduced into the backpropping, it is advisable to make allowance for this in any assumptions made about the loads carried by the props themselves.

Findings in relation to backpropping
When designing backpropping the critical issue is the assumed distribution of load between the levels of supporting slabs.

The conventional approach to the design of backpropping is to assume a uniform distribution of load between supporting slabs. The number of supporting slabs required is then determined by the “spare capacity” of each of the slabs to support the additional weight of the next slab to be cast.

Work from Cardington suggested that, in practice, within the input of significant levels of preload into the backprops, and assuming the slabs to remain essentially elastic, there was very little benefit in having more than one level of backpropping. Further, the uppermost slab of the supporting slabs carries approximately 70% of the load during the construction of the slab above. This can be shown theoretically by considering the stiffness of the different slabs in relation to the props and the arrangements of the falsework and backprops. It was found to hold true over a range of different arrangements of backprops and backprop types (steel or aluminium).

As with many other residential developments, the spare capacity of the slabs at St George Wharf (3 kN/m² unfactored), is very low because of the low level of imposed load specified (1.5 kN/m²). This creates a dilemma since the work from Cardington would suggest that the slab immediately beneath that being cast was 600 mm thick with a self-weight of 14.4 kN/m², three levels of backpropping were employed. Such a configuration would not have been possible to cast this slab using the new criteria unless the beneficial effects of preload are taken into account. This again creates a problem since the permanent works designer would be faced with specifying a level of preload in the backprops that the contractor would not be able to control or verify. In practice such problems can be overcome by both the designer and the contractor taking a pragmatic approach.

Quality control on site concerning the type, positioning, sequencing of placement and removal and tightening of backprops is important and did not always appear to be exercised at St George Wharf in accordance with the calculations presented. Because of the possibility of significant preload being introduced into the backpropping, it is advisable to make allowance for this in any assumptions made about the loads carried by the props themselves.

Interpretation of existing Best Practice guidance concerning backpropping
1. The assumptions made in Table 1, which comes from the Best Practice Guide, were shown not to represent typical site practice, in particular for the backprops to be finger-tight and not relying on any pre-load in them. Where it proves difficult to justify increasing the load bearing capacity of the supporting slab by following the recommendations given in the Best Practice Guide, consideration could be given to applying appropriate levels of preload at the backpropping strips. This would justify the assumption of a mere even distribution of load between supporting slabs, as in conventional approaches. This would more than a nominal amount it would involve specification of a defined level of preload in individual backprops that would be very difficult to control in practice.

2. The use of flat slab formwork and falsework [1] includes a CD with an interactive Excel spreadsheet, illustrated in Figure 2 with sample data. This allows the influence of cracking of the slabs and the effects of pre-load to be taken into account in calculations for up to two levels of backpropping. There is evidence to suggest that there may be merit in extending the scope of this spreadsheet to allow additional levels of backpropping. However, as stated above, the level of pre-load might prove very difficult to control in practice, especially for multiple floors of backpropping.

3. The issue of the design of the backpropping will be most acute for situations where low imposed loads are specified, such as in car parks and residential developments, because of the limited spare capacity of the slabs. Exceeding the design service load of the slabs by a small margin will not be a safety issue, but could have some impact on serviceability performance. The Permanent Works Designer should therefore be involved in any decisions to theoretically overload slabs and should consider possible implications for serviceability.

4. If the developer is closely involved in the design and construction process, as is the case with St George, they can perhaps take a more informed decision as to the relative merits of accepting a higher design load to cater for the construction load conditions.
Use of the spreadsheet
In the spreadsheet the user may set a value for the level of preload in individual backprops. The default value is 6kN per backprop (1), which is believed to be commonly achieved in practice. Measurements of the preload in individual backprops at St George Wharf varied considerably, but averaged 13 kN per prop.

From the point of view of the uppermost supporting slab, it should be recognised that the relieving preload (as measured in kN/m²) is dependent not only on the preload in each backprop but also on the number of backprops.

As an illustration of this, the level of preload chosen in each backprop for trial use of the spreadsheet for St George Wharf was 6kN per prop. This gave a preload in kN/m² similar to that actually measured.

The Best Practice Guide recommends the installation of backprops at the earliest opportunity to assist in the distribution of load between the supporting slabs. In many cases, as with St George Wharf, flying form systems are used which, in practice, usually means that the uppermost slab carries all of the weight of the falsework. The spreadsheet allows this loading to be specified (usually 0.5 kN/m²) and automatically takes this into account when calculating the overall distribution of the load between the slabs. An average backprop stiffness of 23 kN/mm was used, based on measured average values for different types of props. Parameters were chosen to allow the influence of cracking on the slab to be taken into account. These were based on past experience. These parameters resulted in an equivalent reduced modulus of elasticity for a given concrete strength, but these calculated values could have been overridden if desired.

The number and location of the falsework supports and backprops was specified on the basis of the calculations presented for the project. As can be seen from the results for this example, which is for an edge panel with two levels of backproping, the distribution of load between the slabs, taking account of the preload in the backprops, was predicted to be fairly close to the equal thirds split suggested by conventional approaches. In this example the results indicate that the slab immediately beneath that being cast is subject to a construction load very marginally in excess of the design service load.

The spreadsheet allows some interpolation between the two criteria set out in Equations 1 and 2 by virtue of an $E_{ed}$ factor. This factor has been introduced in recognition that Equation 2 is not relevant if the slab is cracked. Equation 2 was introduced to limit excessive strains in the reinforcement. This is explained further in Reference 1.

Conclusions
1. The distribution of loads for the supporting slabs at St George Wharf was found to be close to that predicted by conventional approaches assuming an even distribution of load between slabs once the effect of preload was taken into account. However preloading of the props was not achieved in a controlled manner and in practice would be very difficult to do. This is emphasised by the variations in prop loads measured.

2. If heavily tightened, loads measured in individual backprops can be significant, although variable, and averaged 13 kN for the props instrumented at St George Wharf. This is believed to be higher than the levels of preload generally measured at Cardington. However the overall level of preloading achieved at St George Wharf, (estimated as 1 kN/m²) is not believed to be exceptional.

3. Although slabs may be predicted to be overloaded, they may very well not be so in practice because of the margins on the actual construction load allowed for.

4. Additional margins may be required for the design of the backprops themselves to allow for unintentional preload induced in them during installation and as a result of subsequent temperature changes.

5. To achieve a controlled approach to early age loading the most reliable method would be to follow the existing guidance given in the Best Practice Guide, but the penalty of this approach is that the slabs will need to be designed for a higher loading during construction.

The work undertaken and the conclusions reached in relation to the innovations described above should be viewed in the context of the particular project on which the innovations have been trialled.

This Case Study is underpinned by full reports (2, 3) giving the background and further information on the innovations.

References


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The Best Practice Guide, Early striking and improved backpropping for efficient flat slab construction, summarises work carried out on these topics during the construction of the in-situ concrete building at Cardington.

This can be downloaded free at www.rcc.info.org.uk/pdf/Early_Striking_APP_WEB.PDF and at http://projects.bre.co.uk/ConDiv/concrete%20frame/default.htm. It should be read in conjunction with a companion guide Early age strength assessment of concrete on site.

Case Studies in this series of applying best practice:
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