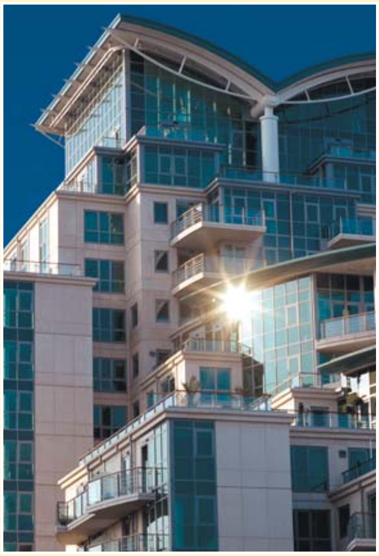
Reinforcement rationalisation and supply

St George Wharf Case Study



Introduction

The European Concrete Building Project at Cardington was a joint initiative aimed at improving the performance of the concrete frame industry. It led to the preparation of a series of Best Practice Guides, giving recommendations for improving the process of constructing in-situ concrete frame buildings.

As part of a programme to disseminate and apply what has been learnt from Cardington, BRE has subsequently worked directly with those involved in St George Wharf, a high-profile, 100,000 m^2 mixed-use phased development on the River Thames.

BRE worked jointly with the developers, St George (South London), their engineers, White Young Green, and specialist concrete contractors, Stephenson, to develop and implement process improvements tailored to the St George Wharf site.

This work has led to a series of innovations being trialled, the results of which are summarised in this series of Best Practice Case Studies.

Figure 1: Loose bars laid around starter bars for column, where shear heads are in position.

Novel approaches to reinforcement supply and rationalisation can help optimize flat slab construction.

Key points

This Case Study discusses experiences and benefits of using electronic exchange of reinforcement information, prefabricated punching shear reinforcement systems and rationalisation of main reinforcement.

- Electronic data interchange (EDI) compatibility in the supply chain for reinforcement is essential if the efficiency of this process is to be improved.
- Interoperable software for the automated supply of reinforcement is more suited to situations where schedules are generated automatically (i.e. as a result of using a computer detailing package).
- It is difficult to generalise about the benefits of varying degrees of rationalisation of reinforcement in terms of cost versus construction time savings as they are project specific and are influenced by market forces.
- The time savings generated by using alternative punching shear reinforcement systems need to be sufficient to warrant the additional material costs.

Electronic exchange of reinforcement Information

The Best Practice guide, *Improving rebar information and supply* (see back cover), highlighted the benefits if all parties in the reinforcement supply chain adopted a common data exchange format to permit electronic data interchange (EDI). This has now become a commercial reality with the availability of proprietary products. Figure 2 illustrates a reinforcing schedule generated using SteelPac (www.Steelpac.co.uk) which was the software chosen for the St George Wharf project. In addition to the basic platform for transfer of the information between parties this can provide added value in terms of intelligent call-off and revision control.

It is understood that the proprietary software used on the St George Wharf project is compatible with the systems of most of the reinforcement suppliers in the UK. However some suppliers (e.g. Express Reinforcement who supplied the reinforcement on this project) are developing their own products. Depending on the pricing structure associated with software, different specialist concrete contractors are opting for different systems; unfortunately it would seem that these are not always compatible with one another. It should be noted that Express reinforcement can and do receive and use schedules generated by SteelPac.

If the additional functionality provided by such proprietary software is not considered advantageous by the contractor, manually generated schedules can still be produced and sent electronically; it is likely that many organisations have developed their own in-house spreadsheets for this purpose. The spreadsheet available at www.structural-engineering.fsnet.co.uk is believed to have the advantage as it has been modified to export to a SteelPac file format, which may then be imported by reinforcement suppliers who have the relevant EDI module.

For the St George Wharf project the detailed drawings and the production of schedules were generally undertaken by hand. It is difficult to say how common this is across the industry as a whole, but the strong likelihood is that this practice is declining with the increasing use of computer detailing software. The most sophisticated software is capable of generating schedules automatically and transferring them electronically. It is understood that the proprietary software used on the St George Wharf project is compatible with all such systems currently available on the UK market.

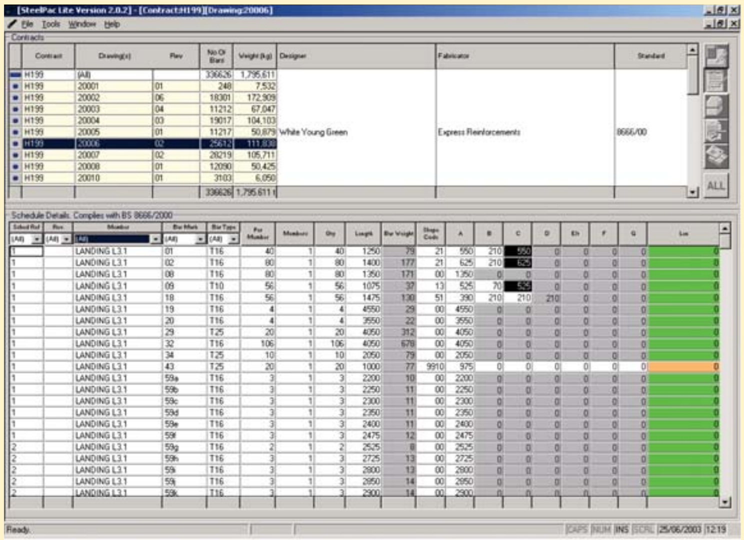


Figure 2: Reinforcing schedule generated using SteelPac

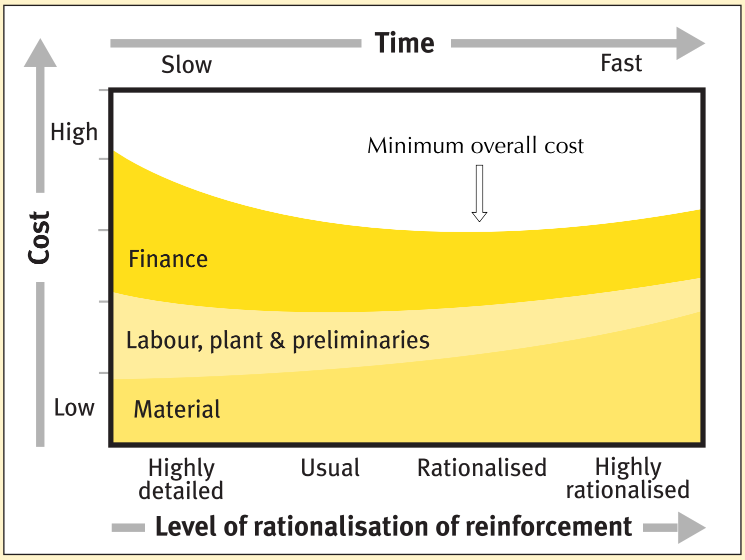


Figure 3: The diagrammatic relationship between rationalisation of reinforcement, time and minimum overall cost.

As with any new software there will be a learning curve and the detailers experienced some teething problems. Since the detailed reinforcement drawings were produced by hand the detailers saw little advantage to them of using such proprietary software. The view of the software supplier, however, is that they did not take full advantage of the facilities offered by their product such as auto-validation of bar marks, auto calculation of cut lengths, weights, etc.

At the stage when electronic schedules were coming on stream, concern about availability of steel meant that there was a sudden requirement to deliver as much steel to site as possible. This prompted the frame contractor to revert to tried and trusted methods but he has since recognised the wider advantages of moving over to electronic systems and is actively taking this forward on the next phase. The detailers are also being pressed to provide this information in a compatible form.

The steel suppliers were initially perceived as the greatest potential beneficiaries of receiving the information electronically, although there are clearly benefits to others in the supply chain.

The advantages for the contractor of using proprietary software on site include more accurate calling-off of reinforcement with less wastage on site, together with traceability. Certainty of supply is enhanced because the software can more easily establish the location of a particular consignment of steel in the procurement and supply process.

Rationalisation of main longitudinal reinforcement

The Best Practice guide, *Rationalisation of flat slab reinforcement,* highlighted the benefits that can be achieved by adopting a rationalised approach*. At St George Wharf, reinforcement in later phases was highly rationalised compared with earlier phases. Historical information is available for a non-rationalised solution on very early blocks (B to D) against which comparisons have been made. These indicate a 21% saving in man-hours for reinforcement where it had been rationalised.

The placing of the main slab reinforcement is invariably on the critical path for the construction of the frame as a whole. Provided it is feasible to bring forward the next pour date, time saved in placing reinforcement will therefore result directly in time savings in the overall programme.

At an early stage, however, it was decided that the benefits of rationalisation at St George Wharf on the blocks investigated (F and G) would be assessed only in terms of savings to the contractor in overall construction costs.

Various options for rationalising the main reinforcement were considered: the use of stock length reinforcement emerged as the favoured solution.

The approach to rationalisation of the reinforcement is likely to vary from job to job, so it can be difficult to draw general conclusions. In most cases, rationalisation of reinforcement should have significant knock-on benefits in terms of simplified detailing, checking and scheduling.

Use of stock length reinforcement on this project meant the provision of a uniform top and bottom mat, typically T12 at 150 centres, for both top and bottom reinforcement in both directions. These stock length bars (12 m) were included in the schedule but had a single bar mark. This basic mat was then supplemented with extra steel as required to meet additional ultimate moment and shear requirements (e.g. over columns) and deflection needs. Cutting on site was minimised by specifying make-up pieces to suit the pour layouts.

Detailing was undertaken by White Young Green who were also the engineers for the project. They were able to respond to the contractor's (Stephensons) requirements in relation to the detailing. The contractor specified the pour layouts, which in turn had a significant impact on the detailing in terms of lengths of bars to suit positions of construction joints. Tailoring of the schedules around the pour layouts also simplified the call-off of the reinforcement as all the bars required for a particular pour could be called off together.

* Rationalisation is the elimination of redundant variation

In practice it proved very difficult to extract meaningful information from the St George Wharf project to assess the level of reinforcement rationalisation adopted. The types of information identified as being suitable measures were:

- Comparison of reinforcement weights which, with information on cost per tonne, could be used to calculate material costs.
- Comparison of fixing time (both elapsed time and man hours per unit area) which, coupled with information on labour rates and total areas, could be used to assess total cost and time.

Successful reinforcement rationalisation involves optimisation of the reinforcement content and economies in the man hours to fix it. Very simple reinforcement layouts can be fixed very quickly. The small cost premium in terms of weight of steel can be more than recovered in time savings both in terms of man hours and overall programme time. For example the contractor quoted typical total reinforcement costs to be 10% – 15% less, provided a rationalised solution is adopted. To examine this cost vs. time relationship, the project specific conditions have to be considered. At the time the work was done, the cost of steel was about £250/tonne, and the cost of employing a steel fixer was around £15 – £20/hour. *

Another factor may be the skill level of the operatives. Greater use can be made of semi-skilled labour if the reinforcement layout chosen is very straightforward.

Punching shear reinforcement

The Best Practice guide *Prefabricated punching shear reinforcement systems for flat slabs* highlighted the benefits that can be achieved in terms of speeding up the provision of punching shear reinforcement.

* Since this work was completed there have been significant increases in the cost of reinforcement. This has skewed the balance between labour and materials, encouraging the use of less material. Recently there have been significant fluctuations (circa £250 - £600/tonne) in material prices over short periods, increasing the difficulty in assessing the appropriate balance between materials versus labour.

At St George Wharf the primary approach adopted was both to reduce the number of columns requiring punching shear reinforcement and to reduce the amount of punching shear reinforcement where it is required. This was achieved simply by increasing the amount of main hogging steel provided over columns, which has the effect of increasing the allowable shear force that may be carried by the concrete (this may not be the most effective method for all cases). Site diaries indicate that as a result the time spent fixing punching shear reinforcement was minimal.

An attempt was made to systematically compare costs and benefits of adopting alternative punching shear reinforcement systems. The systems that it was originally planned to consider were:

DEHA stud rail system
BRC shear rail system
ROM shear ladders
Bespoke cruciform sections.

In this instance only the first two systems were compared with traditional links.

The shear rail system uses shear studs placed on rectangular perimeters whereas the stud rail system has the studs projecting radially from the face of the column.

Both the stud rail and shear rail systems were found to be quicker to fix than traditional links (about four times faster).

Depending on the amount of punching shear reinforcement to be fixed it was concluded that the practical time saving generated needed to be sufficient to merit use of the systems (i.e. the number of days by which the next pour date could be brought forward and thus reduce floor cycle time).

The value of this saving to the programme as a whole should be assessed as well as the direct balance between reduction in man hours offset against the additional material cost of such systems. The Best Practice guide, *Rationalisation of flat slab reinforcement* discusses this in more detail; the issues are presented diagrammatically in Figure 3.

Other factors to be considered are lead times, and approval both by the Permanent Works designer and Building Control. On the St George Wharf phases investigated, these issues were not resolved early enough to allow the systems to be used as a replacement for traditional links. For this particular project, based on very limited data, stud rails arranged on an orthogonal grid and fixed from the top appeared to be the most cost-effective option. The contractor perceived advantages in minimising clashes with main reinforcement and the designer was more comfortable with an arrangement involving more shear reinforcement, which resembled a more conventional rectangular layout.

A steel fixer might prefer simply fixing additional main bars. However, if this is judged not to be cost effective and the steel fixer is required to fix some form of shear system, a system that can be fixed quickly is likely to be preferred.

Conclusions

1. EDI compatible bending schedules generated automatically can be appropriate if suitable computer software is being used to carry out the detailing. However if the schedules need to be generated manually then the advantages to the detailer will be more limited.
2. There is still a need for greater compatibility between different EDI software products, although current market trends suggest that the format used by the proprietary system used on this project is moving towards becoming the industry standard.
3. Software such as SteelPac offers additional functionality over simple spreadsheets in terms of control of call-off of reinforcement. It is understood to have been adopted by most of the major specialist concrete contractors on at least one project.
4. It proved difficult to extract information to assess the level of rationalisation adopted on Blocks F and G at St George Wharf. However it seems likely that the level of rationalisation was very similar to the previous phases as a similar solution in terms of using stock length reinforcement was adopted.
5. Use of highly rationalised layouts has potential advantages to all of the parties involved. The detailing and scheduling is greatly simplified, and so is the calling-off, supply and checking on site. Owing to simplicity, fixing time is reduced with savings in both time overall and man hours; these can outweigh the additional material costs.
6. If steel fixers are paid by the tonne they usually find the use of rationalised layouts attractive.
7. Choice of punching shear system remains with the contractor, who will have his own preferences. These may vary from project to project depending on the tightness of the programme and the extent of punching shear reinforcement required.
8. From the designer's point of view, in the absence of the frame contractor already being involved, the best approach is to specify the parameters for the punching shear design and allow the contractor to formulate proposals.
9. There are still issues to be resolved regarding responsibility for alternative shear designs, certainty of supply of alternative systems, and, if approval is required from the engineer, whether this can be secured in time.
10. Until a successful track record is established with a particular shear reinforcement system, many designers are likely to favour those which deviate least from Code provisions and do not require extensive information from the supplier before gaining approval from the building control authorities.
11. The overall conclusion is that use of alternative punching shear systems is more suited to areas where very large numbers of shear links would otherwise be required.

Recommendations

1. For greatest efficiency in the reinforcement supply chain all parties involved should move towards adopting electronic interchange of schedule information.
2. Ultimately steel suppliers should be pushing for standardised systems as they have the most to gain from receiving information in an industry standard, interoperable format from as many sources as possible.

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 a full report [1] giving the background and further information on the innovations.

References

1. *Best Practice in concrete frame construction: practical application at St George Wharf,* by R Moss. BRE Report 462, 2003.

Acknowledgements

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The following Best Practice guides summarise work carried out on reinforcement issues during the construction of the in-situ concrete building at Cardington. These can be downloaded free from the Downloads section of The Concrete Centre's website at **www.concretecentre.com** and at **http://projects.bre.co.uk/ConDiv/concrete%20frame/default.htm**

- ***Improving rebar information and supply***
- ***Rationalisation of flat slab reinforcement***
- ***Prefabricated punching shear reinforcement for reinforced concrete flat slabs***

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