Temporary Works Toolkit

Part 11: Temporary works associated with precast concrete bridge beam construction

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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Chris Bennion
CEng, FICE, FCIHT, MIED
Kier Group Temporary Works Advisor, UK

Introduction

Current highway bridge designs in the UK tend to favour either composite steel girders with a precast or *in situ* concrete deck for long spans, or precast concrete beams with an *in situ* concrete deck for spans of less than 40m. Relatively few bridge decks are nowadays cast *in situ* on a birdcage scaffold or spanning falsework structure.

This article considers temporary works, in particular the use of temporary supports, to precast concrete bridge beams during deck construction.

The article is aimed at permanent works designers involved with the design elements of this form of construction, as well as civil and structural engineering undergraduate students.

Typical design arrangements

For single-span bridge decks, temporary support is normally undertaken directly from the abutment bearing shelf or equivalent and this is relatively straightforward. Beams to multi-span bridge decks may require a more complex temporary support system if a deck diaphragm cast *in situ* requires separate support.

The provision of continuity across permanent supports reduces stress in the spanning structural members; lighter and/or shallower sections can consequently be adopted. For steel girders, this continuity is relatively easily achieved either by bolted splice plates or by welding. However, the precast concrete option requires an *in situ* reinforced concrete stitch, usually in the form of a diaphragm, to achieve structural continuity. Either the bridge bearings directly support the diaphragm in the permanent condition, or the diaphragm is cast on to the supporting pier(s) to form an integral deck, dependent upon articulation.

The precast concrete beams are designed short in length to facilitate functioning of the above *in situ* concrete stitch. This necessitates some form of temporary support to both the beams and the diaphragm until the beams and diaphragm become structurally monolithic.


Figure 1
Mabey Hire trestle support for precast beams

The common solution is to provide a temporary trestle support founded on the pier base slab (Figures 1 and 2). Beams are landed on the trestle that supports the bridge deck structure until such time that it becomes self-supporting. These trestles can cost significant sums and involve extensive working at height.

Permanent works design considerations

Options for consideration to either eliminate or reduce the requirement for trestles include:

- for deck continuity, arranging post-fixed reinforcement in the spaces between the webs of U beams to enable composite action to take place between the precast and *in situ* concrete elements. The beams would be landed on previously cast portions of the permanent works, designed to include the temporary loading condition
- incorporating high-level corbels in the permanent supporting structure, on which temporary support beams could be subsequently mounted for initial erection and subsequent bearing replacement
- utilising rectangular voids at a high level in bridge piers, through which temporary support beams could be installed. These voids would either remain as a feature or be wholly or partially infilled following removal of the temporary works
- adopting tapered elevations to bridge piers, preferably square section in plan, to facilitate use of a wedged temporary support device fixed

at a high level
- introducing a permanent shelf at a high level, on which precast bridge beams are landed and the *in situ* diaphragm cast.

If trestles are unavoidable, pier base slabs or pile caps need to be sufficiently long to provide an effective foundation to the trestle legs supporting outer bridge beams. The designer should consider allowing trestles to be temporarily tied to the permanent piers for stability purposes via form tie holes or suchlike.

All beams on a single span would normally be erected at the same time due to lifting considerations relating to crane set-up and permissible working radius. The stresses imposed on the permanent works during this temporary condition may exceed those in the permanent condition.

Locations of the permanent-deck jacking points between beam diaphragm and bearing shelf need to be arranged such that jacks capable of lifting the deadweight of the deck (and possibly live load) can subsequently be installed, monitored and removed. Steel bearing plates should ideally be set level in both longitudinal and transverse planes to eliminate horizontal components of jacking load due to long-falls or cross-falls.

It is also worth considering temporary fixings into precast beams at the design stage. For example, this could include anchor bars cast into webs of edge beams for subsequent fixing of cantilever stringcourse support brackets. In addition, these brackets may require restraint against overturning due to wind and further anchors may be required (Figures 3 and 4).

Lifting points for the removal of temporary works and for subsequent maintenance equipment may be provided by casting in sockets into the underside of the deck (Figure 5).

The inclusion of tubular plastic sleeves into the webs of super-Y beams near each end and at third points will facilitate use of strut-and-tie assemblies for stability in the temporary condition.

Temporary works design considerations

Given the consequences of failure and the difficulty of correcting issues that manifest themselves following landing of bridge beams, a robust temporary support structure is a necessity. Factors of safety (as per permissible stress design, e.g. BS 5975[1]) and design factors (as per limit state design, e.g. Eurocodes) may justifiably be amended by the designer to reflect the above.

Safety can be enhanced by building redundancy into the structure. Stress induced from issues such as maldistribution of load, accidental load and out-of-tolerance assembly may be accommodated within redundant structural elements.

Temporary trestles can be constructed using:
- proprietary equipment
- bespoke fabricated steelwork
- reinforced concrete structures
- a combination of the above.

Proprietary equipment is purpose made to be assembled into designed configurations, usually via bolted connections (Figs. 1 and 2). Such equipment is used numerous times in many different circumstances and is maintained by the supplier, who will recommend safe performance criteria. These criteria will be determined either by calculation, tests or a combination of both, with given factors of safety applied.

Fabrication of steelwork offers the advantage that it is purpose designed and built. However, this will be at a cost premium over hiring, for relatively short periods, the equivalent weight of proprietary equipment. Design costs from scratch will be substantially more than those undertaken by the proprietary supplier, who will usually include their design costs in with their hire rate.

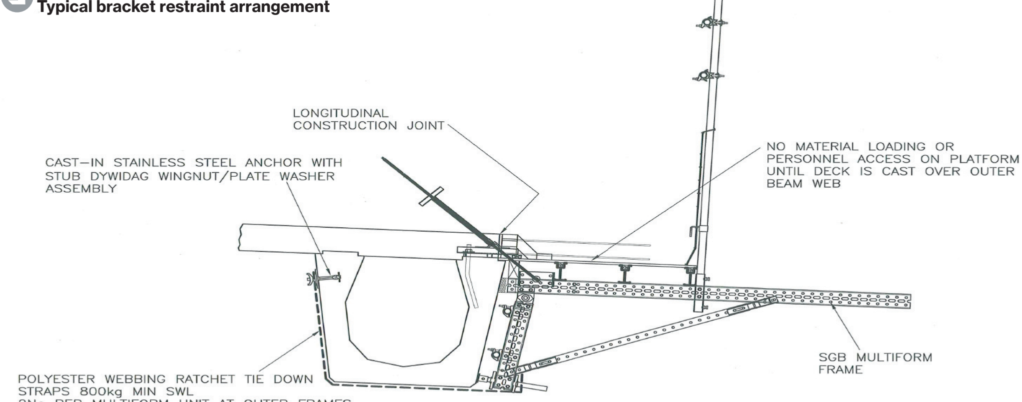
Figure 2
RMD Kwikform Megashor trestle support for precast beams

The use of reinforced concrete as temporary support may be a viable alternative in circumstances where extended periods of use are required. Precast dumbbell-like components may be used to support a high-level temporary steel structure in multiple height configurations, whereas *in situ* support structures would be for one-off use only.

The sequence of precast bridge beam erection should be such that loading occurs between trestle beam supports first, rather than on cantilevered trestle beams. This would eliminate the requirement for high-load-capacity anchors to the foundations and equivalent tensile resistance throughout the structure.

Load paths should be clearly identifiable throughout the structure of the trestle. Each precast bridge beam would typically be temporarily supported on stools or packs. Normally four stools would be used, two at each end of the precast beam. Trestle header beams would be supported on jacks at the top of each trestle leg, founded on the pier base slab. If a precast beam has large resistance to torsion in the longitudinal plane, the entire weight of the beam could be supported on diagonally opposing stools, with the remaining stools acting as restraint against rotation due to, for example, horizontal loads. In this condition, each temporary support should be capable of supporting half the weight of the beam plus the imposed loading.

Figure 3
Typical bracket restraint arrangement



The concrete of the *in situ* diaphragm would typically be supported on a decking assembly consisting of plywood on secondary and primary bearers mounted on the header beams as above, or via a birdcage scaffold from the base slab.

Typical load transfer through a trestle structure will be by direct bearing for vertical loads and either welded or bolted stop plates for horizontal loads.

At bridge abutments, precast concrete beams can be temporarily supported from the bearing shelf outboard of the bearing plinth, if sufficient dimensional clearance exists. Fillets on beams, bearing plinth edges and bearing shelf edges, normally 20mm × 20mm, will determine the area available for temporary supports that may be located either to each side of, or in front of, the bearing plinth. There needs to be sufficient area available such that the compressive stress on the temporary supports and the permanent works is within acceptable limits.

There are several options available for temporary bridge beam support at the bearing plinths. These include:

- hardwood timber wedges
- concrete blocks
- engineering bricks
- proprietary screw-threaded jacks
- hydraulic jacks
- steel stools or plates.

Timber wedges need to be cut to a slope whereby static friction exceeds the component of load down the slope by a clear margin. A slope no steeper than 1V:20H is recommended. The wedges are spiked together after setting to the required level. Striking is achieved by hammering the wedges apart and sufficient space will be required to facilitate this. Wedge reuse is achievable if required.

Concrete blocks of a predetermined strength, cast on site and bedded in mortar to line and level, benefit from a plywood pack taped to the upper surface. This is to assist an even load spread across the block that could potentially fail if point loading occurred during beam landing. Striking is achieved by breaking out the blocks with a pneumatic hammer. Tests have indicated that some plywood can sustain a bearing stress of 10N/mm² with a reduction in thickness of less than 2mm. This compression of the pad assists load distribution. Plywood thickness in the order of 12mm is recommended. Load tests should be carried out on sample blocks to verify suitability.

Engineering bricks are an alternative to concrete blocks, with the advantage that their

Figure 4
Detail at bracket support tie

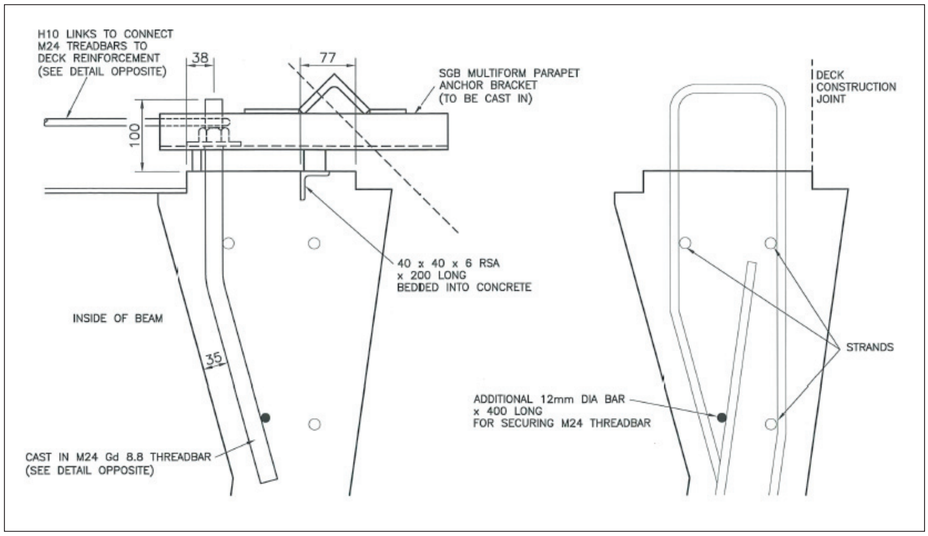


Figure 5
Typical cast-in socket for temporary works removal and subsequent access for maintenance

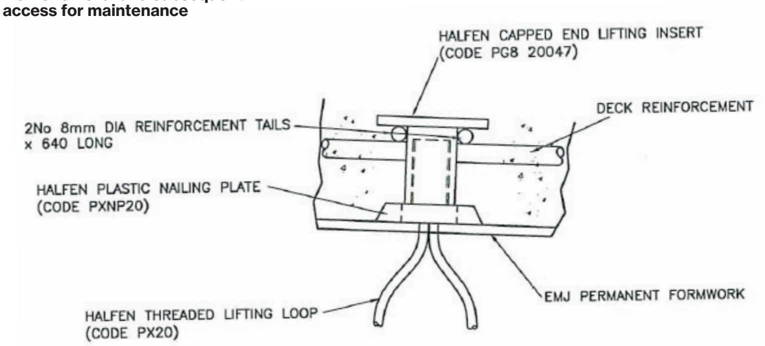


Figure 6
Composite edge beam/parapet/guardrail being installed during night-time railway possession

TABLE 1: KEY DESIGN CONSIDERATIONS FOR TEMPORARY SUPPORT TRESTLES

Consideration	Explanatory notes
Dead load	Self-weight of precast beam, in situ diaphragm, deck portions and reinforcement fixed prior to removal of temporary supports
Live load	Personnel, plant and equipment on deck. As stipulated in design brief
Wind	Wind determined by location. Period of exposure recommended as equivalent to permanent works
Impact	Notional horizontal load, recommended as not less than 10% of beam weight and applied to top of beam support stools
Concrete pressure	Hydrostatic pressure generated on end and sides of beams during diaphragm construction
Setting-out tolerance	Notional horizontal load as per BS 5975
Minimum horizontal load	As per BS 5975
Sliding	Normally resisted by static friction, anchors in shear or packing to permanent works. Long-falls and cross-falls to be considered
Overturning	Stability assessment in temporary condition
Lifting	Enhanced lifting attachments if additional elements (e.g. stringcourses) are cast on site onto bridge beams prior to final positioning

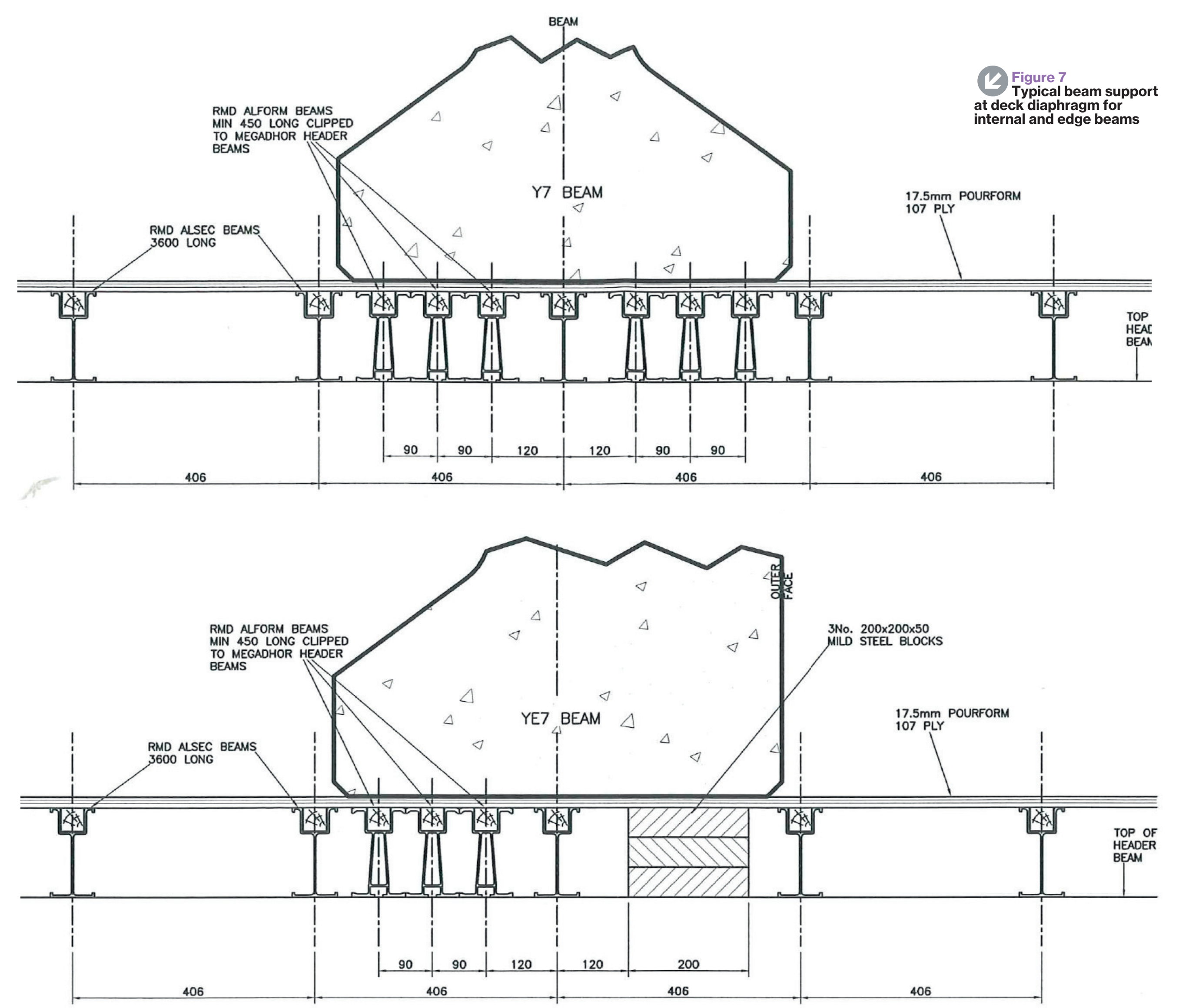


Figure 7 Typical beam support at deck diaphragm for internal and edge beams

Figure 8 Composite stringcourse/ parapet and edge beam supported on curtain wall

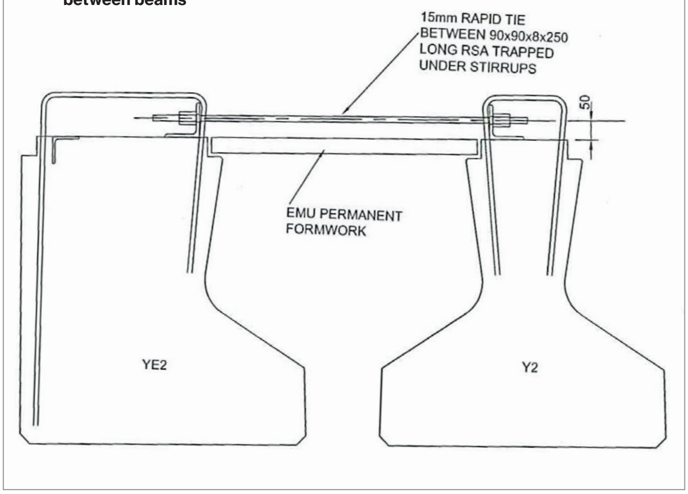


Figure 9 Typical strut-and-tie arrangement between beams

compressive strength is likely to be more predictable due to factory manufacture. However, tests should still be carried out.

Proprietary screw-threaded jacks are available in various load-carrying capacities and sizes. However, there may be restrictions on the induced load whereby manual release of the screw thread is possible. External hydraulic jacking to relieve load in the threaded jack may be required to facilitate striking.

Hydraulic jacks must include the provision of a locking collar. The collar provides a mechanical load path via a screw thread that is independent of the hydraulic support. For safety reasons, hydraulics is only used for fine adjustment of levels during assembly and for striking purposes prior to dismantling. Jacks are normally hydraulically linked to facilitate a controlled release of load on striking.

Steel stools will require fabrication and bedding to level in mortar. Striking is by burning out if mounted on the bearing shelf.

Steel plates provide a non-compressible beam support. This is of use on edge beams with a centre of gravity eccentric to the beam itself due to additional elements being fixed, e.g. stringcourses and guardrails.

To avoid working at height and to provide instant edge protection, the deck parapet/stringcourse may be cast onto the edge beam at ground level and permanent guardrails fixed prior to lifting as a composite unit (Figure 6).

This will alter the centre of gravity of the beam and temporary supports will need to accommodate this. A temporary support that is liable to compression under load, e.g. timber, and placed close to the theoretical centre of gravity will settle once the beam has landed. This may precipitate beam rotation as the centre of gravity shifts and the support settles further. Steel supports assist in the elimination of this potential (Figure 7).

If possible, use should be made of permanent curtain walls to provide a temporary support remote from the centre of gravity of the composite edge beam. The influence upon the permanent works needs to be checked accordingly (Figure 8).

Multiple beams are normally tied together following landing to enhance resistance to horizontal load. This is achieved via scaffold tubes clamped to starter reinforcement or by timber struts used in conjunction with tie rods (Figure 9). Tie rods are best installed through sleeves cast into the beam webs at predetermined positions. This is especially important for the temporary stability of super-Y beams and similar slender sections.

Loading and design considerations

In the UK, design of temporary support trestles would normally comply with the requirements of BS 5975 unless the use of Eurocodes is stipulated as a contractual requirement. Key design considerations are outlined in Table 1.

Conclusion

The permanent works designer's requirements will include providing the client with a design proposal that considers:

- initial design and material cost
- construction cost
- maintenance cost
- demolition cost.

All of these costs will ultimately be borne by the client. By designing out the necessity for extensive temporary works, the permanent works designer can save significant sums for the client. In so doing, they also can minimise working at height and eliminate other associated hazards at source.

It is often stated that the best temporary works are no temporary works. To specifically design out or minimise the necessity for temporary works is a desirable objective to which the permanent works designer should give due consideration. Precast concrete beam installation is an aspect where the permanent works designer can have a marked influence, not only on construction costs but on safety during construction.

REFERENCE

►1) British Standards Institution (2011) ***BS 5975:2008+A1:2011 Code of practice for temporary works procedures and the permissible stress design of falsework*, London: BSI**

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