SAFE DESIGN - ROBUST AND PRACTICAL PROPPING OF SUPER-T GIRDERS

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ABSTRACT

As part of the Peninsula Link Project the project contract documents required that the Designer take responsibility for the design and documentation of temporary propping supports for precast girders to discharge their safe design responsibilities.

From this requirement it evolved that the designer undertook to design temporary propping to a robust standard that included mechanical restraint and design of propping for a range of load conditions above that previously adopted by the contractor in their typical temporary works design.

The project comprised 45 bridges and was completed in January 2013. Across the project the form of the bridges varied and the adopted temporary restraint measures were customised to suit each specific structure whilst maintaining the initial design standard.

INTRODUCTION

Peninsula Link was a A$650m Project to provide a 27 km freeway bypass of Frankston on Victoria’s Mornington Peninsula. The project was constructed by Abigroup under a design and construct commission for the Southern Way Public Private Partnership (PPP) Consortium. The project was designed for Abigroup Contractors (now Lend Lease Engineering) by the SKM-Aurecon Design Joint Venture (DJV) and was opened to the public in January 2013.

As has been prevalent across Australia since the 1990’s (1), Super –T girders were the most common form of bridge construction accounting for 23 of 45 bridges on the project. The project’s Super-T bridges included both conventional and integral bridge forms. In the construction of these bridges the project used 376 Super-T girders equating to nearly 26,000 tonnes of precast concrete the most significant use of Super-T Girders was on the Eastlink interchange bridge which required 108 girders across its nine spans and over 10,000 tonnes of precast concrete.

Super-T Girders

Super-T girders are a common form of precast concrete bridge construction for their design efficiency and value for money. Whilst they provide the primary superstructure for the bridge they also provide a temporary platform for the subsequent construction of the insitu concrete bridge deck slab without significant additional formwork. The Super-T is limited in its use primarily by geometry and span length relating to the fact that girders are constructed off site in a controlled pre-cast yard and then transported. At times the casting yard may be some distance from the site, it is the casting, transportation and delivery limitations that generally restricts Super-T use to a maximum span length of 39m.

The profile of a Super-T is defined in AS5100 (2), whilst there are subtle variations from state to state the typical project Super-T profile is as shown in Figure 1.

A key feature of the Super-T is its flat base. Whilst they are inherently more stable than an individual I-Girder in practice the overall depth of Super-T Girders varies from 1000mm to 1800mm with girders of differing heights cast in a single casting bed with a variable floor. The soffit width tapers for the deeper girders and contrasted against a wide top flange to accommodate the subsequent insitu concrete deck slab. In combination these features can create a potential for overturning particularly for deeper girders.
In their fabrication they are to be supported during casting typically on bearers across their width, and then throughout their handling, storage, transportation, erection and in their temporary installed condition prior to being made composite. Once erected girders are seated on central elastomeric bearings or temporary packers and in the absence of external bracing or propping can only rely on their inertia to resist sliding or self-weight acting at a limited eccentricity/lever arm to resist overturning.

**Safe Design Requirements**

As designers for a project constructed within Australia the DJV has statutory Safe Design obligations under the Model Work Health and Safety (WHS) Act passed in Australia in December 2009 and preceding Victorian legislation.

In the construction industry the applicable reference document is “Model Code of Practice - Safe Design of Structures and Guidance on the Principles of Safe Design for Work” published by the Australian Safety and Compensation Council in 2006 (now Safe Work Australia) (3).

Under this Code of Practice the designer has an obligation to implement a process to facilitate the integration of control measures early in the design process to eliminate or, if this is not reasonable practicable, minimise risks to health and safety throughout the life of the structure being designed.

In the context of this paper this discussion relates to the construction stage and stability of precast elements during their installation. In practice the temporary propping of Super-T Girders is usually considered as a temporary works undertaking which the contractor coordinates, however in this instance the Project Deed (4) Project Scope and Requirements (PSR) Clause 3.8 (g) further specified that “Any fixtures, fittings, bracing or temporary works required to ensure safe erection and maintenance of structures must be fully specified in the Design Documentation.”

On this basis the responsibility for stability during construction could not be discharged or transferred and was incorporated into the detailed design. Under the Project Deed process for the development of Design Documentation required rigorous processes and staging of the
design development with submissions at Concept, Preliminary, Detailed, Certified and Issue For Construction (IFC) all subject to review and comment internally and externally.

At Certified Design the Designer, Proof Engineer, Contractor, Project Company and Independent Reviewer were required to certify that the design was compliant with the PSR and following IFC this process was further applied to changes in Design Documentation. This process resulted in significant scrutiny on the design and in the area of Super-T Girder propping established Robust design standards in a field where design requirements are not explicitly defined.

**DESIGN DEVELOPMENT**

As part of the design development process, each design package was supported by a design report under the Project Deed requirements outlining the design for the benefit of the reviewers and certifiers. Aspects of the design report covered general design package details, adopted design standards, design assumptions, methodology and items for resolution.

With regard to the design of Super-T propping a survey was undertaken of relevant standards. It is apparent from this survey that there was potential for interpretation in this field. Standards identified covered different aspects without specifically nominating the scenario of Super-T:

- AS 1170.1 - Applied loads,
- AS 1170.4 - Wind loading,
- AS 1657 – Fixed platforms, walkways, stairways and ladders
- AS 3600 – Concrete Structures, 2.4.3 Construction Effects,
- AS 3610 – Form Work, 4.3.2 Structural requirements
- AS 3850 – Tilt Up Concrete Construction
- AS 5100 – Bridge Design Code

With regard to contract specific documentation girder stability requirements are addressed for precast concrete unit handling and storage under Vic Roads Specification 620 (5) which requires that “All girders shall be laterally supported. The lateral bracing shall be designed for 10% of the dead load of the girder at the mid height of the beam.”

Vic Roads Specification 613 (6) False-work also includes a requirement to consider “any special conditions likely to occur during construction”

Other states have similar specifications such as RMS NSW – B150 (8), which requires the contractor to “effectively support and brace the girders so as to prevent overturning, unintended sliding and any other unintended movement, when subjected to any loads, including loads induced by handling and environmental factors.

When being placed in position, effectively support and brace the girders before being released by the crane or other lifting device.

Maintain effective support and bracing at all times during subsequent deck forming and concreting operations, and until the deck concrete has hardened."

TMR QLD – MRTS75 (9) is similarly worded.

Whilst the intent of these standards is at times clear there is interpretation in design application for the specific scenario of Super-T Girders.

**Critical Design Actions**

As part of the design development for Peninsula Link it was interpreted that VRS 620 accidental bump load magnitude was appropriate but could conceivably be applied at any height in the girder, most critically at the level of the top flange as the adjacent girder is craned into position.
Other load considerations included temporary hand rail construction loading and wind loading on the girder in elevation including potential hoarding to top of handrail height. Super-T Girders seated on bearings resist these actions in overturning and sliding.

The three major load cases assessed are summarised as follows.

- Wind loading. Design wind speed of 35 m/s (125 kph), A drag coefficient of 2.0 and no shielding was considered, as the bridge span was always exposed. In the edge girders the temporary platform for lateral construction access was also assumed to take some wind effect, and a 50% porosity was considered across the height of a projecting 1100mm high hand rail under the design wind speed.

- Accidental bump effect. This load was applied at one edge and as discussed above was applied as a horizontal acceleration of 10% of the girder self-weight under gravity. This load was applied at the top flange. The assessed magnitude of 10% could conceivably be by a girder in motion during a crane slewing motion or under wind load when the girder’s potential energy is discharged to the adjacent previously erected girder.

- Self-weight of temporary platform and handrails to be installed adjacent to the edge girder and corresponding vertical 2.5 kPa live load and horizontal 0.75 kN/m live load applied once beams are installed.

By their nature these loads are specific to each structure and require assessment based on a set of variables specifically including girder span, height and self-weight and from structure to structure different load cases may be critical as demonstrated in Table 1. The consideration of the bump load discussed above can result in an increase in design action of 90% for larger girders as compared to other design actions typically implemented.

### Table 1: Typical Girder Design Actions

<table>
<thead>
<tr>
<th>Super T Girders Depth (m)</th>
<th>Typical Girder Length (m)</th>
<th>Typical Girder Weight (Tonnes)</th>
<th>H* ULS Constr Load (kN)</th>
<th>H* ULS Wind Load (kN)</th>
<th>H* ULS Bump Load (kN)</th>
<th>M* ULS Constr Load (kNm)</th>
<th>M* ULS Wind Load (kNm)</th>
<th>M* ULS Bump Load (kNm)</th>
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<td>7.5</td>
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<td>40</td>
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<td>95</td>
<td>92.9</td>
<td>85.8</td>
<td>171</td>
</tr>
</tbody>
</table>

**Detailed Design Proposal**

From previous projects the contractor had applied a variety of measures including low level seating brackets, vertical props under flanges, props under girder bottom flange or supporting props fixed to the abutment or pier shelf. These solutions were typically applied at low height or were reliant on friction and not capable of resisting the design actions of the magnitude in Table 1.

From a safety perspective it was apparent to the design team that the requirements of AS3850 should be applied specifically including a minimum of two mechanical fixings per element removing a typical reliance on friction. Also given the potential for the generally critical bump load to be applied at any location along the girder the full bump force had to be resisted by each mechanical connection.

Using this assumption and in designing the system for Ultimate Limit State there was some contingency in the design by providing for full impact load at each restraint. Efficiency was also provided via the assessment of girders in groups once installed. This design intended that when any girder was being installed, the previous girder or group of girders were already fully attached together and safely fixed to abutments or crossheads, and in that way there was a secure and progressive installation of the remaining girders. These lateral supports were
required only during construction stage, and only able to be removed after the concrete slab was entirely cast.

In every bridge the first two installed girders were attached to abutments and crossheads at each end by diagonal props that provided restraint against both overturning and sliding. In wider bridges requiring large number of beams; additional diagonal props were included at interior beams, this account for some redundancy in the system, and for possible on site staggering in sessions for completion of the entire spans. Figure 2 shows a typical elevation of the propping arrangements.

![Figure 2: Elevation view- arrangement of temporary restraints](image)

For the temporary fixing of the girders to piers and abutments, the project documented two types of arrangement depending on the conventional or integral abutment details of bridge. Propping designs were documented on standard detail drawings included in a typical details package and supported by structure specific requirements in each bridge package.

**Conventional bridges**

Diagonal push/pull struts were specified attached to the web faces of girders where there was sufficient room to accommodate these props. Connection ferrules were documented on girder drawings and cast in to the end diaphragm. Abutment fixings were post fixed into the top face of the abutment shelf. To provide efficiency adjacent Super-T girders were tied together at the flange level by horizontal threaded tie bars with a hooked anchor plate secured around the projecting shear ligatures. Refer figure 3.

![Figure 3: Plan view- arrangement of temporary restraints in a skewed bridge](image)

**Integral bridges**

The detailing of bridges without expansion joints and integral abutments was a feature of the Peninsula Link Project (9). With regard to girder propping it presented a minor complication as the construction of the abutment beam is cast in stages, first to an adequate level to provide girder support, and then subsequently to fully anchor the precast girder into the abutment and deck slab.

Based on this requirement for the integration of the girders into the abutments, starter bars were left in the space where the temporary propping was specified for conventional bridges. As an alternative for the case of integral bridges, the abutment shelf was cast with an internal step to assist with development length of lapping tension reinforcement.
An innovative solution looked for the best way to install the girders maintaining stability and avoiding the existing starter bars required for subsequent stages. The solution comprised a system using threaded tie rods and brackets to be installed at the end face of girders connecting to the shelf. This system made use of post fixed anchors installed prior to erection and threaded rods acting in tension only and that required a diagonal fixing on each side for the critical girder. With use of threaded rods and rotating brackets with a single fixing there was additional flexibility in adjustment on site. To achieve this, the connecting anchor bolts were fixed to the end face of the girder and then to the vertical face of the upstand of the construction joint within the abutment diaphragm. Figures 4 and 5 compare the typical treatments for conventional and integral bridges.

![Figure 4 & 5 - Typical anchor details – side face conventional side face and integral back face of Super-T beam](image)

**Construction Phase Issues, Suitability & Modification**

During the construction phase there was ongoing design support from the DJV typically relating to providing clarification on design intent or correcting errors and omissions, assessing the implication of elements or materials constructed outside specification limits and assessing alternatives to make the construction more efficient, or alternatively propose alternatives to add value.

The Construction Phase Services process included a clear change control process was used to ensure that the propping arrangements were correctly documented. In accordance with the project Quality Plan and specification VRS 613 the Contractor’s Nominated Authority and the Proof Engineer provided the site presence to approve false-work under the PPP Deed in the absence of the traditional Superintendent’s role.

The Designer’s role was limited to the provision of Design Documentation as previously described. At construction stage quality in design documentation was maintained via the project’s rigorous Request for Information and Design Change Note process.

Using these processes the DJV provided assessment of as built propping girder configurations, alternative fixing details, alternative props and confirmed minimum design requirements were maintained without compromising safety or integrity.

As an example to obtain certification for the alternative threaded rod arrangement for integral bridges which was documented after IFC had been achieved for relevant design packages the following steps were taken:

- Contractor raises RFI to DJV CPS team
• Contractor and DJV discuss and DJV document alternative

• The proposal was drafted and presented with a design query to be reviewed by proof engineer (SMEC) and the DJV’s internal verifier.

• PE and DJV IV provided comments where applicable or requested clarifications. Then the designer provided responses to comments in an iterative procedure seeking for approval from both parties by the expedition of an appropriate certificate.

• DJV issue Design Change Note with certificates to Contractor

• Contractor issue Design Change Notes with Certificates to Independent Reviewer (Role required under PPP to ensure compliance with Project Deed in this instance Balfe AECOM)

• IR provides comment or certifies and issues Design Change Note to Southern Way (Project Company)

• Southern Way endorse and return to Contractor/DJV for design documentation to be amended to IFC.

The above process whilst time consuming was rigorous and necessary and is common on major projects in particular PPP’s where there are a number of internal and external stakeholders who require oversight to ensure that the Project Deed requirements are executed.

CONCLUSIONS

From the experiences of this project the authors wish to highlight the following conclusions:

• Whilst use of Super-T girders is widespread and design is standardised the minimum requirements for stability of Super-T Girders are not explicitly defined and are open to interpretation. Consideration should be given to defining them in AS5100 as the consideration of a 10% bump load can result in an increase in critical design action of 90% for larger girders as compared to other design actions typically implemented.

• Statutory Safe Design obligations should be supported by designer and contractor interaction with the designer effectively discharging their responsibilities. Robust design should be supported by a thorough review and certification process and design change control process.

• The designer must continuously consult with the contractor to ensure that practical solutions are provided and effectively implemented. Efficient and practical solutions can be achieved without compromising design standards, integrity and safety.

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Adam McManus is a Chartered Engineer with over fourteen years’ experience working as a civil/structural engineer in Australia, Ireland and New Zealand. During this time he has been involved in a wide range of engineering projects working as part of large and small design teams, gaining experience as a designer and manager both within the office and on site specialising in the design of bridges and civil structures. Adam was involved in the Peninsula Link Project as part of the Aurecon SKM Design Joint Venture from tender then through detail design as a Team Leader and as Project Leader through the construction phase to completion. Adam is currently based in Perth where he is an Associate in Aurecon’s Perth Transport Team. Adam has previously authored/co-authored three Austroads Bridge conference papers.

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