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UPGRADING OF RAILWAY BRIDGE AT WOLLI CREEK, SYDNEY

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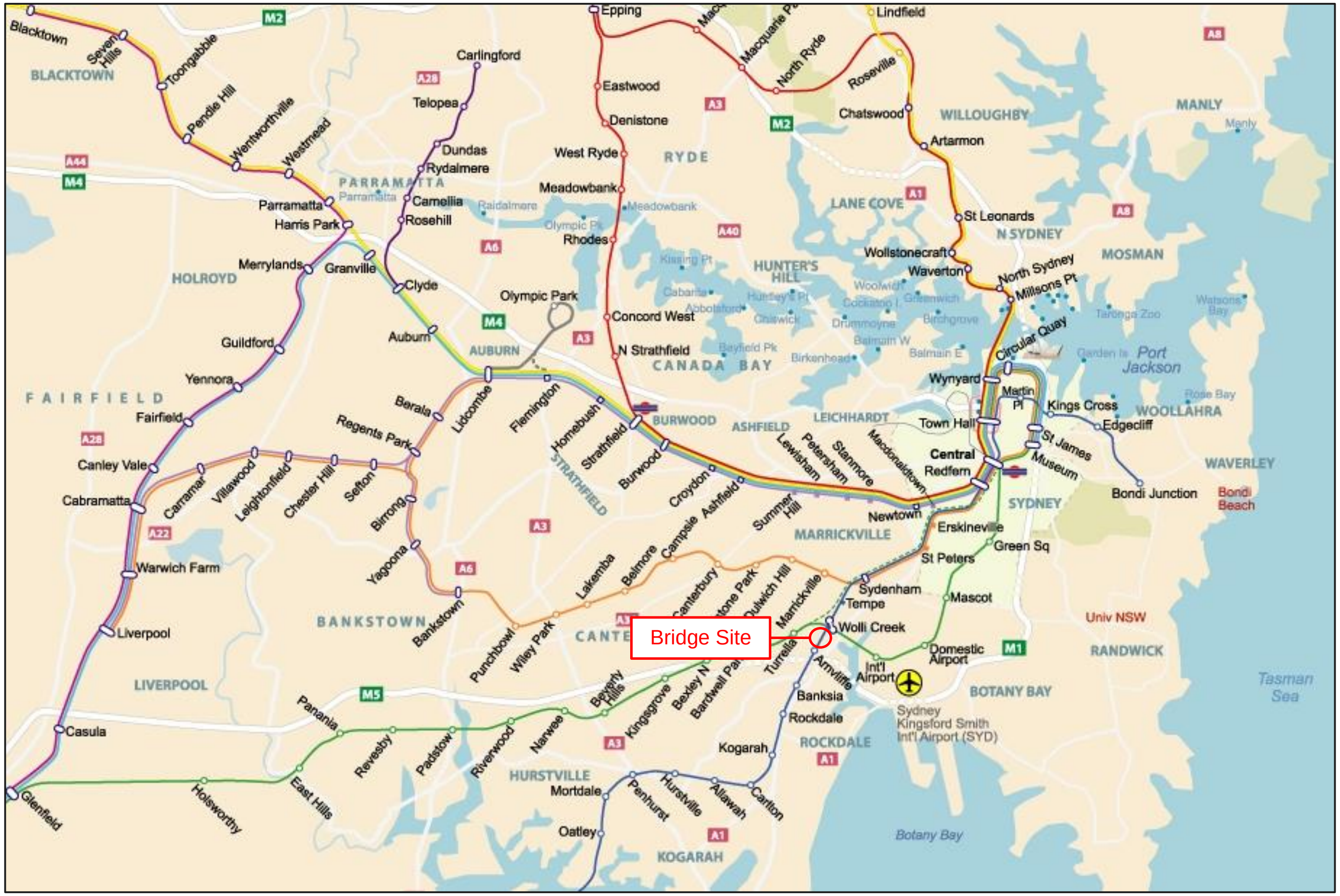
Incorporating Hyder

Outline of Presentation

- Original underbridge.
- Recommended replacement superstructure.
- Assessment of existing abutments.
- Superstructure replacement design.
- Installation of superstructures.
- Time-lapse video (3½ minutes).

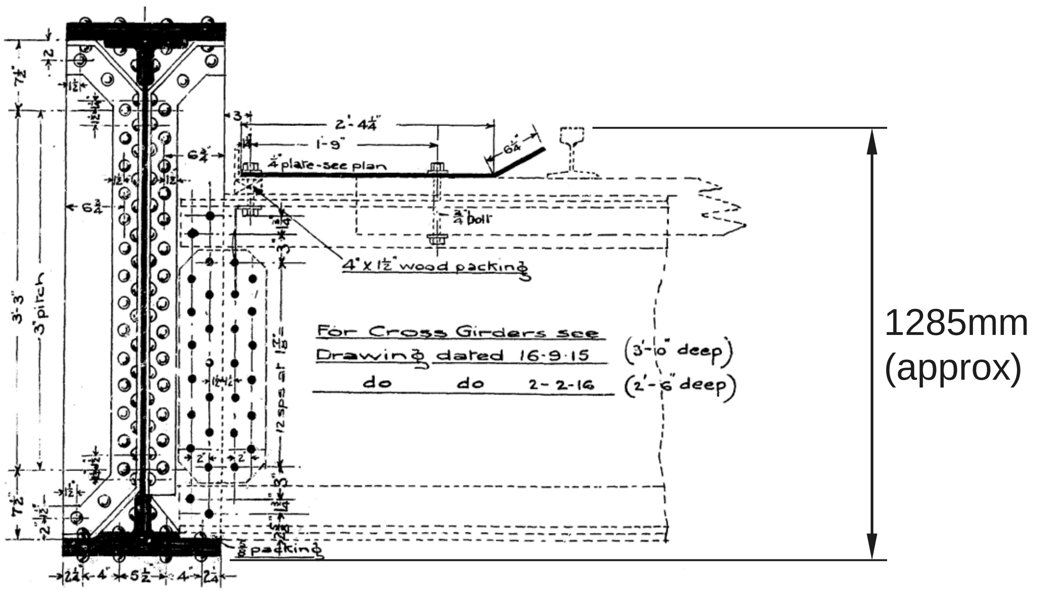
Bridge Location – Wolli Creek, Sydney



Original Underbridge

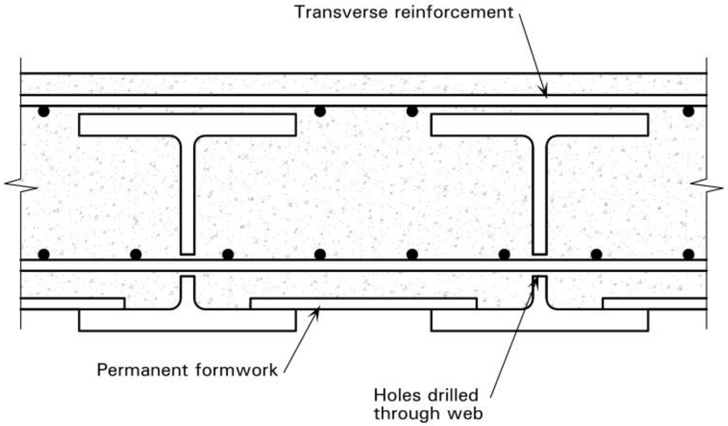
- Two (2) side-by-side separate transom-top riveted steel half-through girder superstructures, supported on brick abutments.
- Span 13.1m.
- Superstructures installed in 1915 and 1923.

Original Underbridge (continued)



- Not feasible to replace with a ballast-top superstructure (overall construction depth of 1820mm).
- Direct rail fixation only option.
- Sydney Trains allows direct rail fixation, but requires single monolithic girder under each track.

Filler Beam Bridge Deck

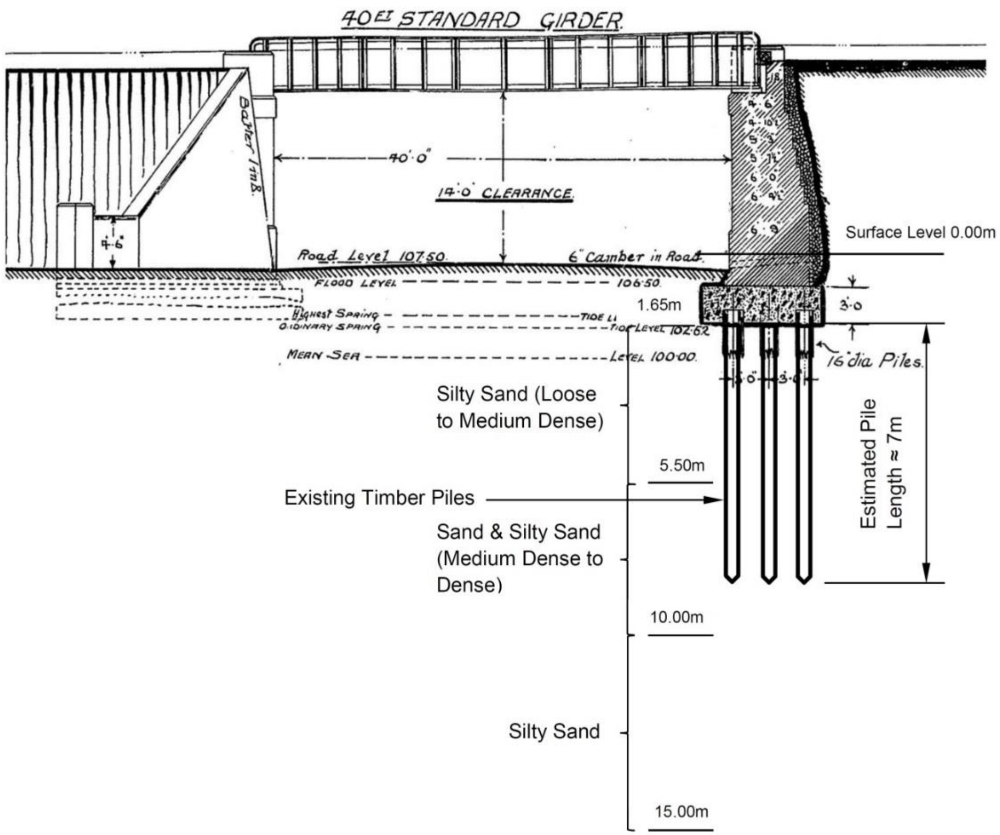


- Relatively popular in continental Europe (typically insitu construction).

Filler Beam Bridge Deck (continued)

- Design not covered in AS 5100 *Bridge design*.
- Design previously covered in BS 5400 Part 5: *Code of practice for the design of composite bridges*.
- BS 5400-5 superseded by Eurocode 4 – *Design of composite steel and concrete structures – Part 2: General rules and rules for bridges*.
- Significantly stiffer compared to same depth reinforced and prestressed concrete sections ⟶ deflection advantages.
- Higher span-to-depth ratios compared to reinforced and prestressed concrete ⟶ advantageous where construction depth is to be minimised.

Existing Abutments – Assessment



- Vertical load-carrying capacity, estimated settlement and stability of the existing abutments to satisfactorily support the new superstructures were assessed.
- Previous total superstructure mass 112 tonnes & proposed superstructure mass 498 tonnes.
- Existing abutments were considered satisfactory to re-use, without strengthening or underpinning being required.

Filler Beams – Geometric Criteria (Eurocode 4)

6.3 Filler beam decks

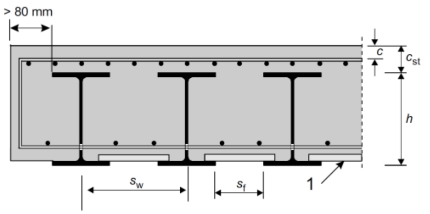
6.3.1 Scope

(1) Clauses 6.3.1 to 6.3.5 are applicable to decks defined in 1.5.2.14. A typical cross-section of a filler beam deck with non-participating permanent formwork is shown in Figure 6.8. No application rules are given for fully encased beams.

NOTE: The National Annex may give a reference to rules for transverse filler beams

(2) Steel beams may be rolled sections, or welded sections with a uniform cross-section. For welded sections, both the width of the flanges and the depth of the web should be within the ranges that are available for rolled H- or I- sections.

(3) Spans may be simply supported or continuous. Supports may be square or skew.



Key:

1 non participating formwork

Figure 6.8: Typical cross-section of a filler beam deck

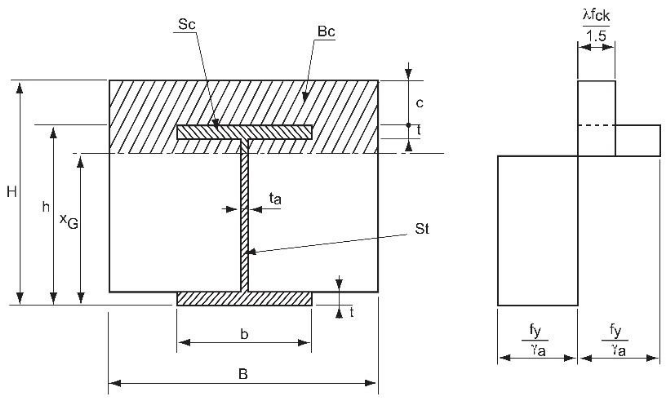
(4) Filler-beam decks should comply with the following:

- the steel beams are not curved in plan;
- the skew angle θ should not be greater than 30° (the value $\theta = 0$ corresponding to a non-skew deck);
- the nominal depth h of the steel beams complies with: $210 \text{ mm} \leq h \leq 1100 \text{ mm}$;
- the spacing s_w of webs of the steel beams should not exceed the lesser of h/3 + 600 mm and 750 mm, where h is the nominal depth of the steel beams in mm;
- the concrete cover c_{st} above the steel beams satisfies the conditions:

  $$c_{st} \geq 70 \text{ mm}, \quad c_{st} \leq 150 \text{ mm}, \quad c_{st} \leq h/3, \quad c_{st} \leq x_{pl} - t_f$$

  where x_{pl} is the distance between the plastic neutral axis for sagging bending and the extreme fibre of the concrete in compression, and t_f is the thickness of the steel flange;
- the concrete cover to the side of an encased steel flange is not less than 80 mm;
- the clear distance s_f between the upper flanges of the steel beams is not less than 150 mm, so as to allow pouring and compaction of concrete;
- the soffit of the lower flange of the steel beams is not encased;
- a bottom layer of transverse reinforcement passes through the webs of the steel beams, and is anchored beyond the end steel beams, and at each end of each bar, so as to develop its yield strength in accordance with 8.4 of EN 1992-1-1: 2004; ribbed bars in accordance with EN 1992-1-1: 2004, 3.2.2 and Annex C are used; their diameter is not less than 16 mm and their spacing is not more than 300 mm;
- normal-density concrete is used;
- the surface of the steel beams should be descaled. The soffit, the upper surfaces and the edges of the lower flange of the steel beams should be protected against corrosion;
- for road and railway bridges the holes in the webs of the steel section should be drilled.

Filler Beam Flexural Design – UIC Code 773



The ultimate moment is the maximum moment, which a cross-section can resist before failure. This moment is obtained, when all the materials of the cross-section become plastic.

Calculation of M_{Rd}

Calculation of the position of the plastic neutral axis x_G :

For the equilibrium of the cross-section the force resulting from the tension stresses in the beam must be equal to the sum of the forces resulting from the compression stresses in the steel and concrete.

$$F_{St} = F_{Bc} + F_{Sc}$$

$$F_{St} = \frac{f_y}{\gamma_a}\left[bt + t_a(x_G - t)\right]$$

$$F_{Sc} = \frac{f_y}{\gamma_a}\left[bt + t_a(h - t - x_G)\right]$$

$$F_{Bc} = \frac{\lambda . f_{ck}}{1.5}\left[B(H - x_G) - bt - t_a(h - t - x_G)\right]$$

$$\frac{f_y}{\gamma_a}(bt - t \cdot t_a) + x_G\frac{f_y}{\gamma_a}t_a = \frac{\lambda f_{ck}}{1.5}\left[BH - bt - t_a(h-t)\right] + x_G\frac{\lambda f_{ck}}{1.5}\left[t_a - B\right] + \frac{f_y}{\gamma_a}\left[bt + t_a(h-t)\right] - x_G\frac{f_y}{\gamma_a}t_a$$

$$x_G = \frac{\frac{\lambda f_{ck}}{1.5}\left[BH - bt - t_a(h-t)\right] + \frac{f_y}{\gamma_a}t_a h}{\frac{\lambda f_{ck}}{1.5}(B - t_a) + 2\frac{f_y}{\gamma_a}t_a}$$

The resulting ultimate moment is the sum of the moments of these forces related to X_G :

$$M_{Rd} = F_{Sc}x_{FSc} + F_{Bc}x_{FBc} + F_{St}x_{FSt}$$

Calculation of x_{FSt}: distance between the resulting F_{St} to x_G

This is the position of the centre of gravity of the tension zone of the steel.

$$x_{FSt} = \frac{\frac{t_a(x_G - t)^2}{2} + bt\left(x_G - \frac{t}{2}\right)}{t_a(x_G - t) + bt}$$

Calculation of x_{FSc}: distance between the resulting F_{Sc} to x_G

This is the position of the centre of gravity of the compression zone of the steel.

$$x_{FSc} = \frac{\frac{t_a(h - x_G - t)^2}{2} + bt\left(h - x_G - \frac{t}{2}\right)}{t_a(h - x_G - t) + bt}$$

Calculation of x_{FBc}: distance between the resulting F_{Bc} to x_G

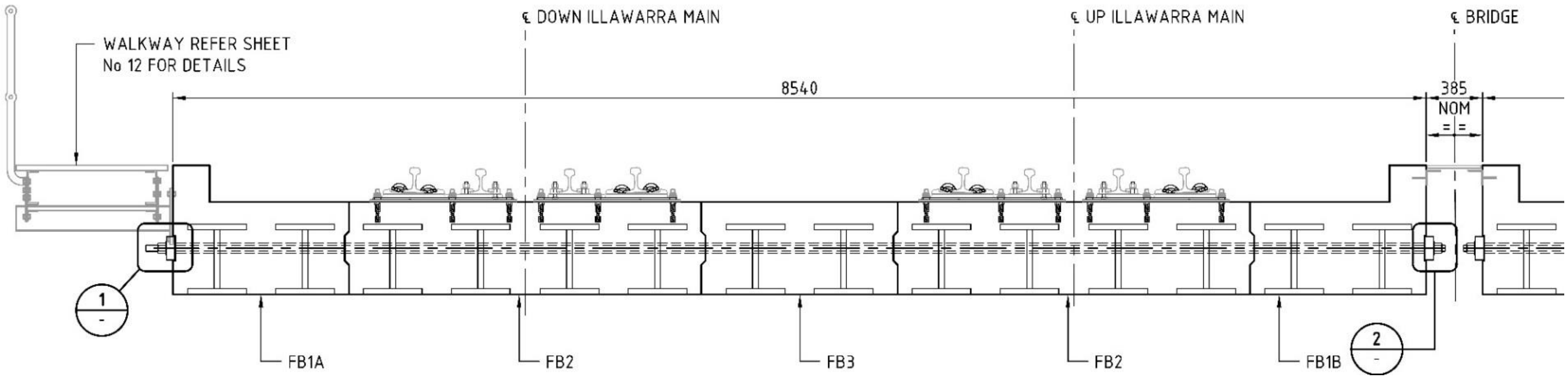
This is the position of the centre of gravity of the compression zone of the concrete.

$$x_{FBc} = \frac{B(H-h)\left(\frac{h}{2} - x_G + \frac{H}{2}\right) + t(B-b)\left(h - x_G - \frac{t}{2}\right) + (B - t_a)\frac{(h\ \ x_G\ \ t)^2}{2}}{B(H - x_G) - bt - t_a(h - x_G - t)}$$

Filler Beam Design – Features

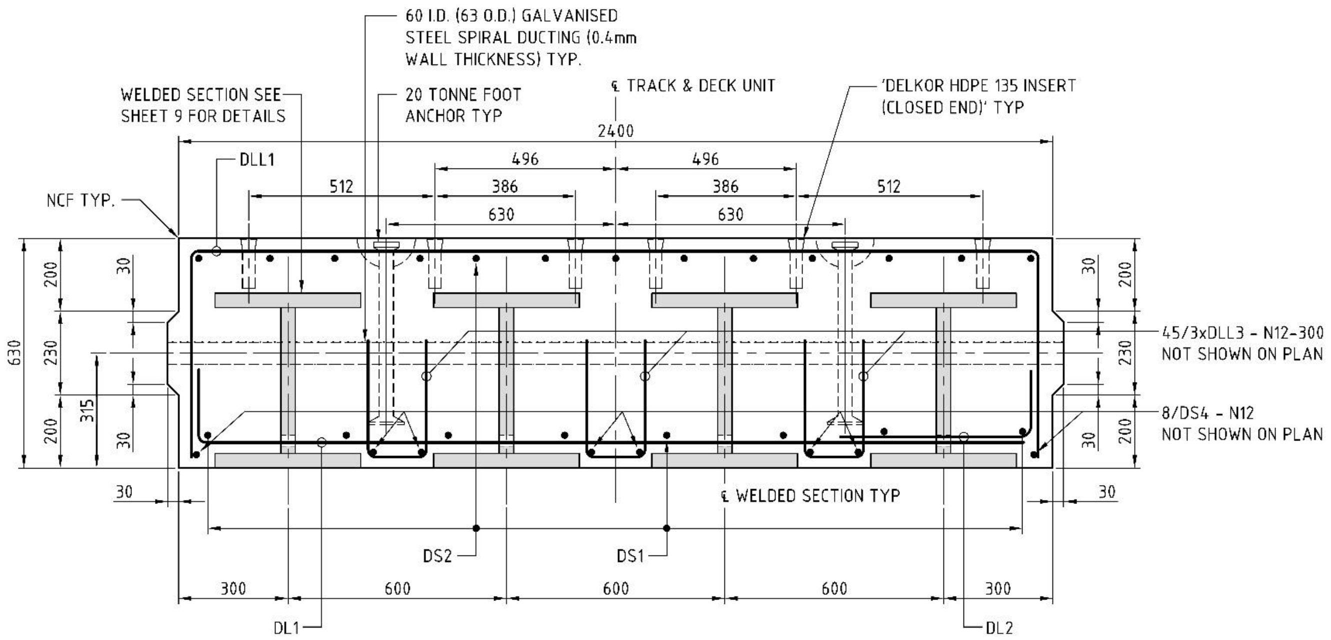
- Deflection typically governs design (AS 5100: ΔLL ≤ span/640).
- Transformed section for $I_{uncracked}$ and $I_{cracked}$. $I_{effective} = 0.5 (I_{uncracked} + I_{cracked})$.
- For RC sections $I_{effective} \approx 0.55\ I_{uncracked}$ but for filler beam sections $I_{effective} \approx 0.9\ I_{uncracked}$. Steel is the dominant strength material in the cross-section.
- Span-to-depth ratio of 20.6.
- Plastic moment capacity.
- Match cast units with shear keys.
- Transverse post-tensioning across the segmental superstructure improves interaction between adjacent deck units by creating orthotropic plate structural behaviour.
- No shear studs/connectors required. Composite action achieved through steel/concrete bond.

Replacement Superstructures



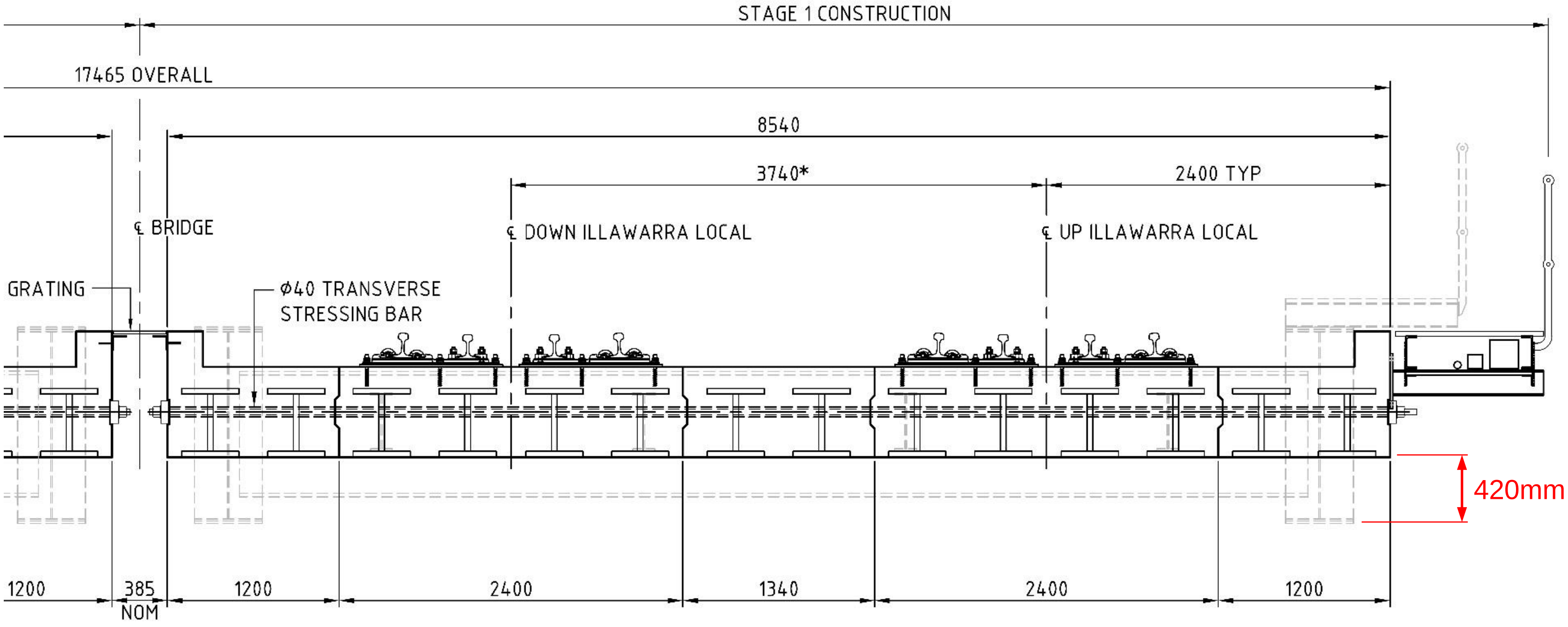
- Deck units were match cast and comprised either two (2) or four (4) concrete encased steel sections.
- Deck units widths: 1200mm, 1340mm & 2400mm.
- Transverse post-tensioning (high tensile steel bars – Macalloy Bar).

Filler Beam Deck Units



- Approximate mass of 2400mm wide filler beam deck units (13.6m long) = 67.7 tonnes (with Delkor rail plates attached).
- Full-penetration butt welds at the flange/web connections of the built-up encased steel I sections (Sydney Trains requirement).

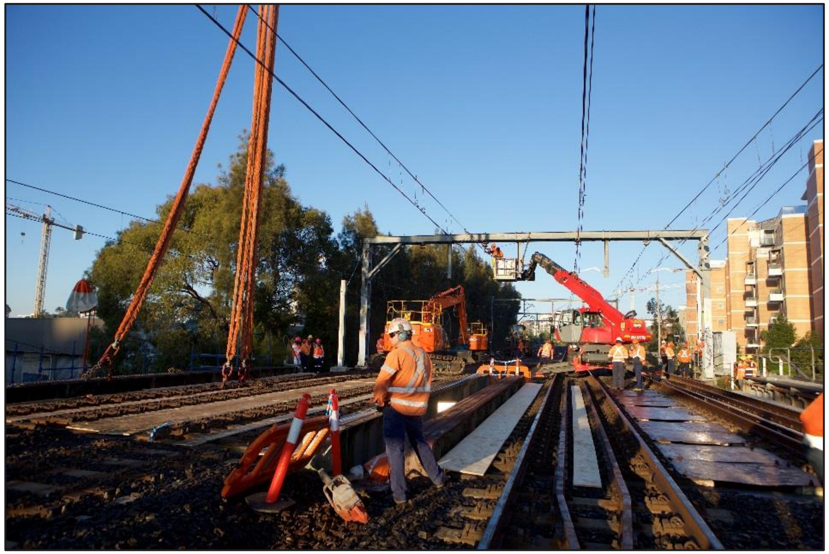
Comparison – Superstructure Depths



Track Possessions

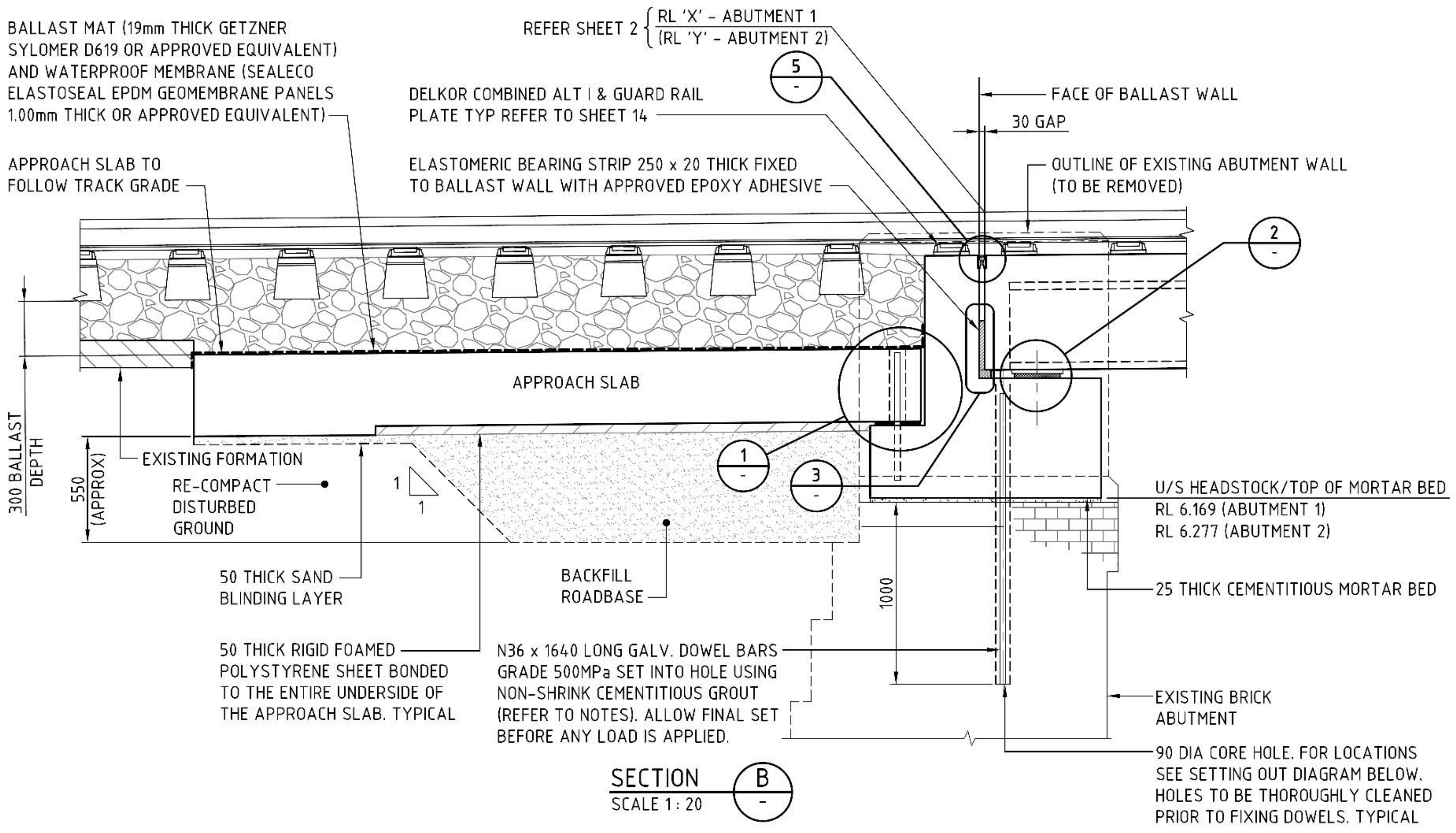
- Two (2) superstructure installations carried out over two (2) 48-hour track closures.
- Last weekend of June 2015 and first weekend of July 2015.
- For such limited construction periods, precast and prefabricated elements are used extensively.

Preliminary Works



- Overhead wiring shifted sideways.
- Removal of original steel superstructure.

Abutment Arrangement



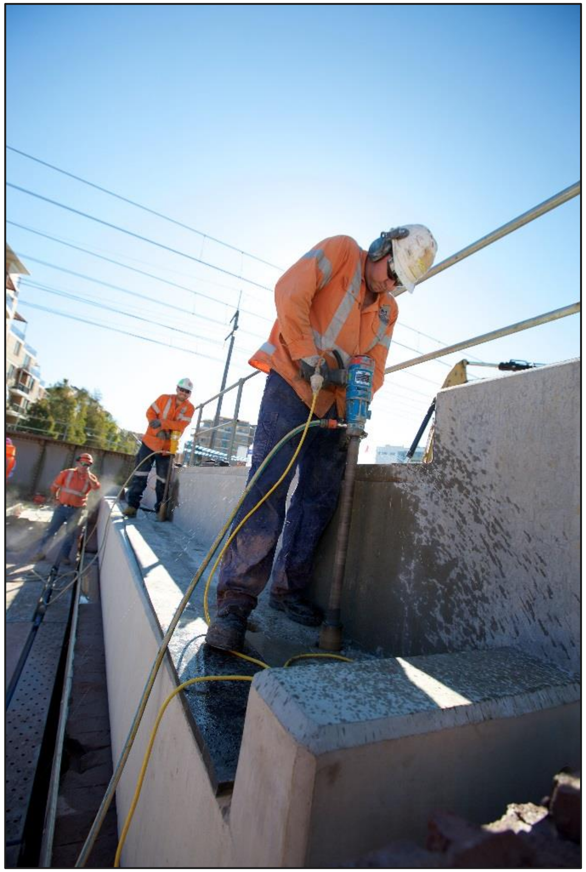
Installation of Headstocks & Superstructures

- Prior to the first track possession, 750 tonne crawler crane was assembled adjacent to the Sydney abutment, beside the railway tracks.
- Horizontal saw cutting of the abutment ledges to accommodate the proposed precast concrete headstocks was carried out on the Friday afternoon of each track possession (during train running).
- Installation of abutment headstocks, including bearing strips.
- Installation and grouting of vertical steel dowels connecting new headstocks with cut-down brick abutments.
- Installation of deck units.
- Transverse post-tensioning of completed deck.
- Installation of track rails, including inner guardrails.

Abutment Preparation

- Preparation of cut-down abutment ledges.

Precast Abutment Headstocks

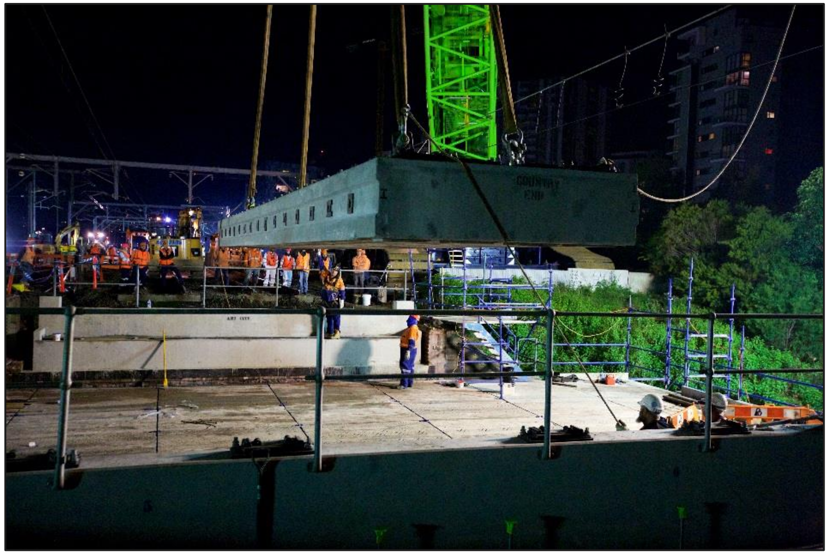


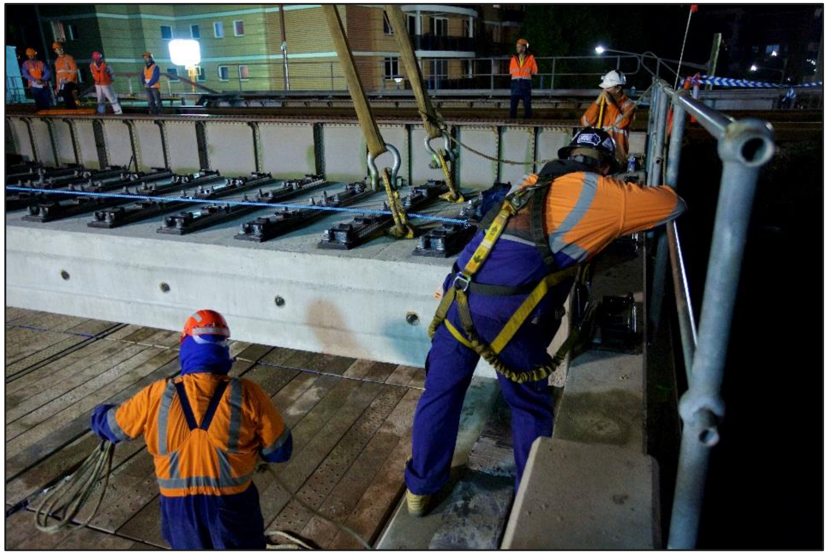
- Drilling into brick abutment for steel dowels.

Precast Abutment Headstocks (continued)

- Precast abutment headstock on mortar bed on cut-down brick abutment (steel dowel connected).
- Note staged construction.

Deck Unit Installation





- Installation of ‘track’ deck unit.

Deck Unit Installation (continued)

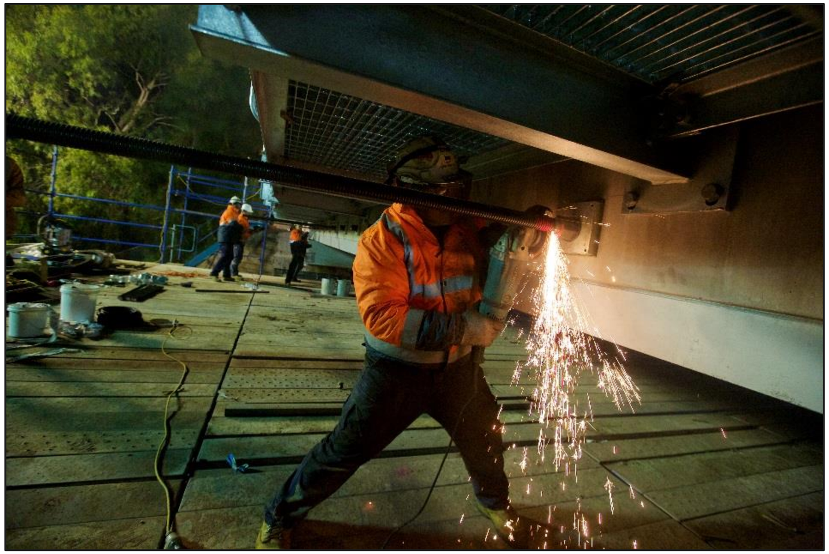
- Installation of inner deck unit.
- Compressible filler to prevent grout loss.

Post-Tensioned Transverse Tie Bars

- Installation of tie bar.

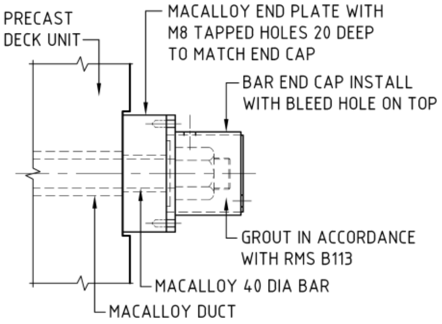
- Stressing of tie bar.

Tie Bar Completion

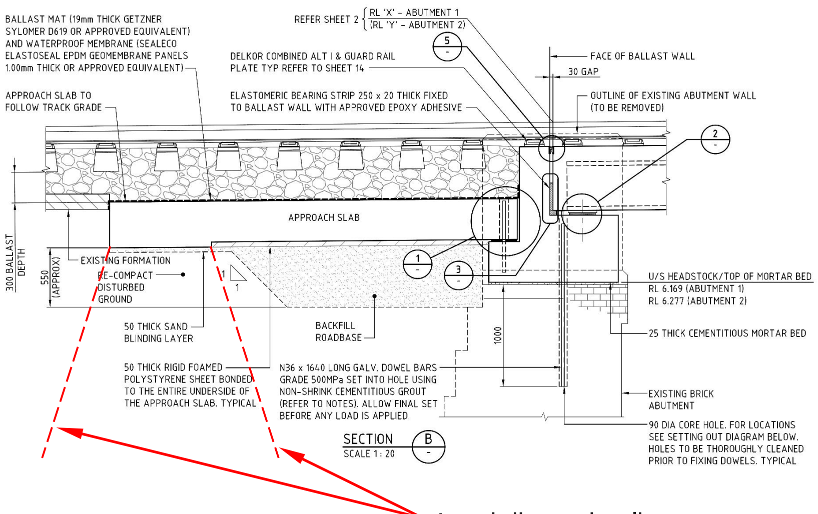


- Friction cutting excess tie bar length – heat from the friction of contact is sufficient to remove the metal by melting it.

End Cap Assembly



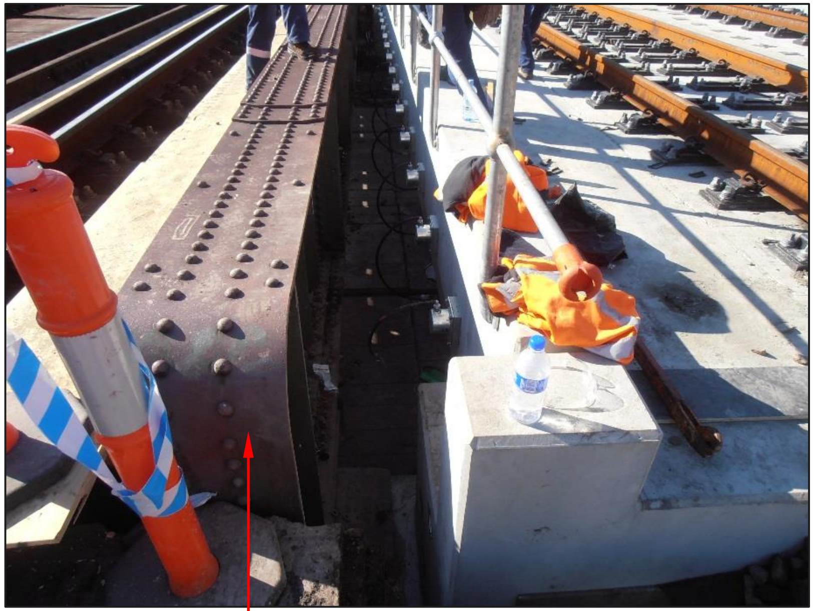
Precast Approach Slabs

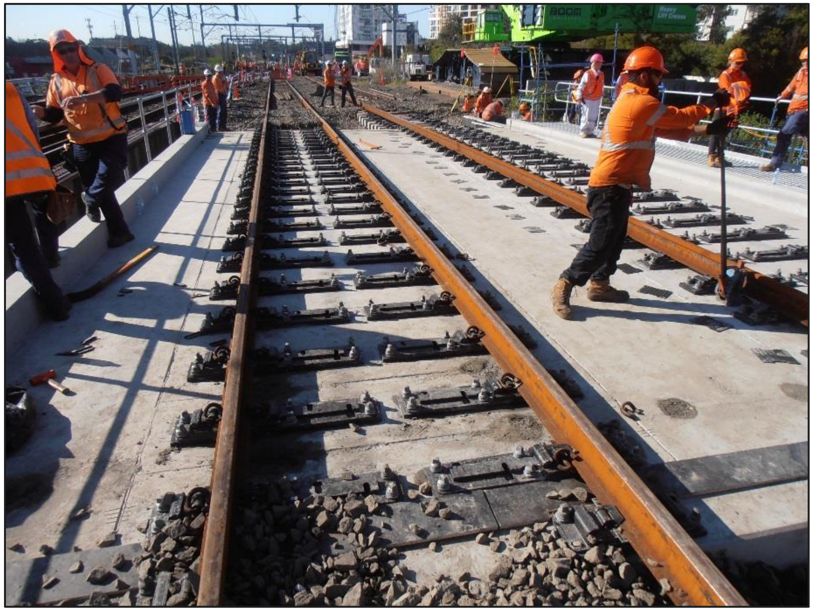


Load dispersion lines

- Sydney Trains requirement to reduce/eliminate live load surcharge on rear of old re-used bridge abutments.

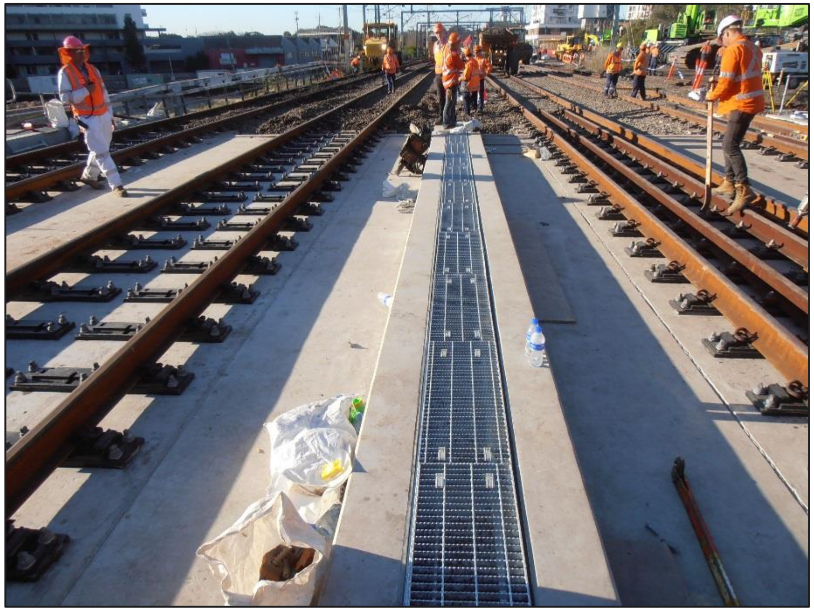
Completion of First Superstructure





Steel superstructure to be replaced
in 2nd track possession

Completion of Second Superstructure



- Installation of rails.

Ready for Service

Old v New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4.0 m
ADVERTISE
HERE
85723915
ADVERTISE
HERE


LOW CLEARANCE
ADVERTISE
HERE
ADVERTISE
HERE
1300 779 954

Concluding Remarks

- Suitable for situations where vertical clearance to be increased.
- Suitable form of construction for limited track possessions.
- First time Sydney Trains has installed direct rail fixation filler beam deck units – reportedly pleased with outcome.

Time-Lapse Video

Acknowledgement

Thank you to Sydney Trains for:

- Allowing access to the site during the superstructure installation work.
- Supplying a large quantity of photographs and the time-lapse video of the construction work.

Thank you for your attention