Code of Practice
Sign gantries and lighting masts

1. Scope and introduction

BTN014 Sign gantries and lighting masts states VicRoads' requirements for the design and construction of the structures listed in AS5100.1 Cl 23.1.

Bridge Technical Notes are a Code of Practice. Compliance with Bridge Technical Notes is mandatory.

BTN014 is to be read in conjunction with the following VicRoads/DOT standard sections. Where there is a conflict between this BTN and a standard section, this BTN shall prevail.

- Standard Specification 760
- Standard Specification 630

Other than as stated in this document and relevant VicRoads standard specifications, the provisions of AS5100:2017 shall apply. Where this document differs from AS5100:2017, its requirements override those of AS5100:2017.

This document also provides additional mandatory requirements for design and construction which are intended to reduce the risk of fatigue failure of the listed structures.

Fabrication shall be in accordance with VicRoads Standard Specification 630.

2. Geometry

The maximum horizontal length of the cantilever arm of sign structures shall not exceed 9m. Further recommendations for the treatment of cantilever arms of horizontal length greater than 9m are given in Section 9.

3. Foundations

3.1. Foundations

Cantilever and gantry sign structures shall be supported on a piled foundation. The maximum permitted settlement of piled foundations shall be determined on the basis of a geotechnical investigation and in any event, shall not exceed 5mm over the design life.

3.2. Mounting

Sign gantries shall not be mounted on bridge barriers. If it is necessary to mount a cantilever or gantry sign structure on a bridge, the mounting point shall be independent of the bridge barrier.

4. General design

Signs shall be side-mounted, positioned in front of the gantry arm and connected to the top and the bottom flanges of a gantry arm box section. Signs shall be positioned vertically such that the loads on the connections between the sign framing structure and the gantry arm(s) are minimised as far as possible. Two or more gantry arms should be provided if required to support two rows of signs or to reduce connection loads to comply with fatigue limit state design.

All stiffener and gusset plates that are required to transfer load at connections between sign supports and gantry arm members shall be external to the gantry arm members. These plate elements must be designed for all relevant limit states including buckling.

Where signage loading on an existing gantry is to be modified, a full structural and geotechnical assessment of the proposed changed gantry shall be undertaken. Where material properties are not known, materials testing shall be performed.

5. Fatigue limit state design

When configuring a structure, and choosing and designing connection details, primary consideration must be given to making certain that the structural detailing ensures that the structure will have good fatigue strength and be fit for purpose over its design life. Details must be configured and designed to ensure that a smooth transfer of stress flow from a member into a connection is achieved.

5.1. Lighting masts – fatigue design

Fatigue limit state design for lighting masts shall be in accordance with the current edition of the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1]. All aspects of fatigue design shall be based upon the AASHTO publication [1], including drag coefficients, fatigue importance factors, fatigue stress categories and constant amplitude fatigue limits.

High-mast light poles that could fall onto marked traffic lanes or shoulders shall be treated in accordance with AASHTO [1] requirements for Fatigue Category I. Refer also to clause 5.3 below.

5.2. Sign gantries – fatigue design

Fatigue design loads for sign gantries, including drag coefficients, shall be calculated for an infinite fatigue life, Fatigue Category I in accordance with the current edition of the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1]. Refer also to clause 5.3 below.

Notwithstanding clause 13.11.3 of AS5100.6-2017, all other aspects of steel fatigue assessment and design shall be based upon the current version of AS5100.6, unless noted below. The fatigue requirements of AS5100.6-2017 are largely taken from the International Institute of Welding (IIW) recommendations as described in Recommendations for Fatigue Design of Welded Joints and Components [2]. This IIW document [2] provides comprehensive and thorough explanation of the fatigue requirements in AS5100.6-2017 and designers are advised to consult it.

- AS5100.6-2017 shall be amended as follows:
  - Sign gantries shall be designed for an endurance of 100 million cycles i.e. $N_R = 1 \times 10^8$ cycles Therefore;

    AS 5100.6-2017 equation 13.11.1(3) shall be replaced by:

    $$\frac{\gamma_{Ff} \times \Delta\sigma_S}{\emptyset_{Mf} \times \Delta\sigma_R} \leq 1.0$$

    AS 5100.6-2017 equation 13.11.1(2) shall be replaced by:

    $$\frac{\gamma_{Ff} \times \Delta\tau_S}{\emptyset_{Mf} \times \Delta\tau_R} \leq 1.0$$

    Where:

    $\Delta\sigma_S$ and $\Delta\tau_S$ are the design fatigue stress ranges calculated from AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1], then modified by factors k_t and k_1 as required by AS5100.6 and;

    $\Delta\sigma_R$ and $\Delta\tau_R$ are read from AS 5100.6-2017 Figures 13.10.1(A) and 13.10.1(B) at N = 1×10^8 cycles or;

    $\Delta\sigma_R$ and $\Delta\tau_R$ are calculated from AS 5100.6-2017 equations 13.10.1. (3) and 13.10.1(4) at $N_R = 1 \times 10^8$ cycles.

    $\Delta\sigma_R$ and $\Delta\tau_R$ shall be modified by factor k_s as required by clause 13.10.3.2, AS5100.6-2017.

  - Use γ_{Ff} = 1
  - Use capacity reduction factor for fatigue strength $\emptyset_{Mf}$= 0.75
  - Use damage equivalent factor λ = 1
  - Use dynamic load allowance α = 0
- Connection details must have robust and clearly defined load paths such that a smooth transfer of stress flow from a member into a connection is achieved. There shall be no sudden changes in geometry or stiffness at load transfer zones and stress concentrations must be minimised.
- Gantries shall be detailed to avoid conditions that create highly constrained joints and crack-like geometric discontinuities that are susceptible to constraint induced fracture. Refer to AASHTO LRFD Specification for Bridge Design Cl 6.6.1.2.4 [3].
- If a preferred detail is not represented in the fatigue detail category tables in AS5100.6, reference may be made to the nominal stress tables in the current AASHTO LRFD Specification for Bridge Design [2] and the current AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1]. However, when using these standards, the design constant amplitude design fatigue strength must be determined at 1×10^8 constant amplitude stress cycles for the specific detail.
- Where a preferred detail is not represented in AS5100.6 or the AASHTO standards listed above [1][3], the detail shall be reconsidered, and the connection and/or structure reconfigured so that a represented fatigue detail can be used.
- Finite element analyses may not be used to determine the design fatigues stresses for details that are not represented in the AS5100.6 or AASHTO S-N fatigue curves and detail tables [1][3]. Typically, robust and extensive full-scale physical testing regimes are required as a part of a rigorous procedure to establish the fatigue strength for details that are not represented on current SN curves. Finite element analyses are not accepted on their own as adequate to determine fatigue strength without being backed up by rigorous physical testing carried out in accordance with international standards. Refer to Cl.13.5 of AS5100.6-2017 and Cl C.1 Appendix C of AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1].
- Where there is a small variation to a detail (that is reasonably represented in the AS5100.6 or AASHTO S-N curves [1][3]), the appropriate stress concentration factor to convert nominal stress range to geometric stress (also called hot-spot stress) can be determined from relevant literature. Alternatively, geometric stress (also called hot-spot stress) can be calculated using an elastic Finite Element [FE] analysis. The elastic FE analysis shall be in accordance with DNVGL-CG-0127 Class Guideline on Finite Element Analysis [3] and Recommended Practice DNVGL-RP-C203 [4]. The hot spot stress shall be calculated in accordance with Recommended Practice DNVGL-RP-C203 [4] or IIW Recommendation for Fatigue Design of Welded Joints and Components [2].

5.3. Calculation of fatigue loads - general

The AASHTO [1] publication provides values of equivalent fatigue-limit-state static wind pressure ranges without requiring consideration of the site-specific wind loading. The wind pressure ranges used in the AASHTO [1] formulae were obtained following consideration of a range of installation sites across the USA. For high-mast light poles AASHTO [1] requires the equivalent fatigue-limit-state static wind pressure range to be selected based upon the yearly mean wind velocity. For these structures, the maximum value of equivalent fatigue-limit-state static wind pressure range shall be used, unless a lesser value is justified based upon detailed wind records taken over a period of at least 50 years. Adjustment may be required for differences in the averaging interval used for wind speed data in Australia and in the USA.

Sign gantries may also be susceptible to a resonant response from along-wind buffetting if the structural system is too flexible. The natural frequency of the structural system shall be greater than 1 Hz.

The potential for a resonant response of the cantilever arm of cantilever sign structures to vortex shedding originating from the column shall be assessed, including designs in which steel box sections are used for the principal members. If a resonant response is possible, this shall be mitigated in the design (for example by the installation of impact dampers or wind-flow spoilers).

6. Materials

6.1. Grout

The design shall be prepared on the basis that all loads are supported by the anchor-bolts. No account shall be taken of the capacity of the grout to support compressive loads.

Grout shall be proprietary pre-mixed, free-flowing, non-shrink material with a minimum strength of 50MPa in accordance with Standard Specification 760.

Also refer to Appendix A for grouting requirements.

Dry-packed mortar shall not be used.

6.2. Steel

Further to AS/NZS5100.6 Cl.14.4, for the purpose of selecting the grade of steel, the design service temperature shall be taken as LODMAT – 5ºC.

7. Preparation of designs

Designs for sign structures and lighting masts shall be prepared by a designer that is prequalified at Structures Complex level in accordance with the VicRoads scheme for prequalification of consulting engineers.

8. Proof engineering of designs

Designs for sign structures and lighting masts shall be subjected to proof-engineering by an engineer that is prequalified at Proof Engineering level in accordance with the VicRoads scheme for prequalification of consulting engineers.

9. Additional requirements for cantilever sign structures with cantilever arms of horizontal length greater than 9m

In order to ensure that cantilever arms of length exceeding 9m will have an adequate fatigue performance, it is advised that they shall be subjected to vibration monitoring for a period of 12 months. As a minimum, vibration monitoring shall be achieved by measuring variations in strain at the base-plate weld in order to establish that the strain range is less than the relevant constant-amplitude fatigue limit defined in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [1].

Proposals for vibration monitoring together with the collection and interpretation of data shall be subjected to proof-engineering by a company that is prequalified at Proof Engineering level under the VicRoads scheme for prequalification of consulting engineers.

References:

1. AASHTO. 2015. LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, First Edition. American Association of State Highway and Transportation Officials. Washington, DC.
2. IIW. 2019. Recommendation for Fatigue Design of Welded Joints and Components, Second Edition. International Institute of Welding, A.F. Hobbacher, 2019.
3. AASHTO. 2017. LRFD Bridge Design Specifications, 8th Edition. American Association of State Highway and Transportation Officials. Washington, DC.
4. DNVGL. 2015. Class Guideline DNVGL-CG-0127 Finite Element Analysis, October 2015.
5. DNVGL. 2011. Recommended Practice DNVGL-RP-C203 Fatigue Design of Offshore Steel Structures, October 2011.

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Bridge Technical Notes are subject to periodic review and may be superseded.

Appendix A

Construction

Installation of anchor-bolts

Following erection of the column, all levelling nuts in double-nut moment connections shall be initially tightened to snug-tight to capture the base-plate with nuts effectively tensioned against both sides of the baseplate.

Top-nuts shall then be tensioned by the part-turn method as follows:

Anchor-bolt diameter < 37.5 mm 1/6 turn beyond snug tight

Anchor-bolt diameter > 37.5 mm 1/12 turn beyond snug tight

Anchor-bolt template

In order to maximise the fatigue performance of the base-plate connection, a double template shall be used in order to achieve correct positioning and alignment of the cast-in anchor-bolts and the bolt holes in the base-plate. A suitable arrangement is described in NCHRP469 Fatigue- Resistance Design of Cantilevered Signal, Sign and Light Supports, Figure C-5.1 and comprises a pair of steel ring with nuts on both sides - one ring cast in at the lower end of the anchor-bolts, and one removable ring at the upper end of the anchor-bolts.

Grout

Grout shall be mixed in accordance with the manufacturer's recommendations using a mechanical mixer which has sufficient volume to mix all of the grout required for one base-plate in a single mix. Grout shall be placed within the maximum time limit recommended by the manufacturer.

Grout-testing shall be in accordance with Standard Section 760.

Formwork

If formwork is not properly sealed, grout leaks may occur leading to the formation of voids under the base-plate and potentially to a heightened risk of corrosion of steel components. The following procedure is recommended in order to avoid the possibility of grout leakage.

Formwork Procedure

The design intent is to provide a layer of grout with minimum thickness of 75mm between base plate and foundation. Formwork on three sides of the base-plate shall be set at to a minimum height of 75mm. Formwork on the fourth side is then set to a level 10mm higher than the underside of the base-plate.

The grout shall then be poured into the side opposite the low side in a continuous operation such that the grout flows continuously and freely over the formwork on the low side, ensuring no voids.

Neither the formwork, base-plate or grout shall be vibrated or tapped. Grout shall then be cured in accordance with the manufacturer's instructions.

Document Control

Version	Date	Description	Approved by
1.0	01/01/18	Original Publication	Principal – Bridge Engineer
1.1	15/06/18	Amended Section 3 and Section 5	Principal – Bridge Engineer
1.2	17/10/18	Amended Section 4	Principal – Bridge Engineer
1.3	30/11/18	Amended minor errors	Principal – Bridge Engineer
2.0	31/10/19	Fatigue Design Provisions	Principal Engineer – Structures
2.1	20/11/19	Amended minor errors	Principal Engineer – Structures