NZ Transport Agency Highway Structures Design Guide

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Abstract: The NZ Transport Agency (the Transport Agency) issued in May 2016 the first edition of the Transport Agency's Highway Structures Design Guide.

This new document is the Transport Agency's primary structures design document, and sets out the Transport Agency's design requirements for all permanent highway structures on the New Zealand state highway network, including soil structures and earthworks.

The primary function of the Highway Structures Design Guide is to define design requirements that are consistent with the Transport Agency's primary purpose of promoting an affordable, integrated, safe, responsive and sustainable land transport system.

The guide has secondary functions of (a) providing design guidelines for use by other New Zealand road controlling authorities, (b) interpreting the New Zealand Building Act 2004 requirements for the design of highway structures and setting out the Transport Agency's intended means of compliance with the New Zealand Building Code, and (c) providing the Transport Agency's requirements for structures owned by others that are present within the state highway road reserve.

In addition to comprehensive design requirements for new structures (including design philosophy and non-structural requirements as well as structural requirements), the scope of the Highway Structures Design Guide includes design and construction process requirements, design, construction and handover documentation requirements, a summary of Building Act 2004, Building Code and building consent requirements and requirements for evaluation of and alterations to existing structures.

The guide references the Transport Agency's existing structures design manuals, guides and specifications, but also contains new material developed where found to be necessary in order to provide comprehensive coverage of the Transport Agency's structures.

The paper, prepared by the working group that developed the Highway Structures Design Guide, describes the genesis and development of the guide, provides a section by section summary of the content and presents and discusses the new requirements that have been developed.

Keywords: highway, structures, design, guide, development.

1. Background and Development of Guide

In 2012 the NZ Transport Agency's (the Transport Agency's) National Office Structures Team of the Highways and Network Operations Group commissioned a strategic review of the Transport Agency's structures documents. One of the key recommendations of the review was that a single overarching structures design document was needed, that would be the first 'port of call' for designers seeking the Transport Agency's design requirements for any highway structure.

Development of the guide commenced in 2013, by a small working group consisting of the authors of this paper. Initially a framework was developed, allowing the intended purpose and scope of the document to be clarified and agreed. Once the framework was complete, references to existing Transport Agency documents were added where appropriate. This process allowed gaps in the Transport Agency's existing range of documents to be identified. Text was then drafted for the guide to fill many of the gaps, and a separate study was commissioned to recommend design requirements for some minor structure types. When a first draft was substantially complete, reviews from other Transport Agency staff, consultants and suppliers were sought and comments addressed. Finally, the guide was formally ratified by the Transport Agency's Ratification Group and was published as the Highway Structures Design Guide (1) 1st edition in May 2016.

2. Purpose, Function and Scope

2.1 Purpose and Function

The Highway Structures Design Guide (1) sets out the NZ Transport Agency's design requirements for all permanent highway structures on the state highway network. It also sets out the Transport Agency's design requirements for earthworks, including natural slopes, embankments and cuttings.

The primary function of the Highway Structures Design Guide (1) is:

- To define design requirements for highway structures on the state highway network that are consistent with the NZ Transport Agency's primary purpose of promoting an affordable, integrated, safe, responsive and sustainable land transport system.

Secondary functions are:

- To provide design guidelines for highway structures for use by other roading authorities throughout the road transport network that are consistent with the NZ Transport Agency's primary purpose.
- To interpret Building Act 2004 (2) requirements for the design of highway structures and to set out the intended means of compliance of highway structures with the Building Code (3).
- To provide the NZ Transport Agency's design requirements for structures that are not Transport Agency owned, but are present within the state highway road reserve.

2.2 Scope

The scope of the Highway Structures Design Guide (1) is as follows:

- design and construction process requirements, including requirements for structure options reports, structure design statements and technical approval, for design and construction review and for certification
- design, construction and handover documentation requirements
- a summary of Building Act 2004 (2) requirements for the design of highway structures, including Building Code (3) and building consent requirements
- design requirements for new structures including design philosophy, non-structural requirements, structural design requirements and Building Code (3) compliance requirements
- design requirements for alterations to existing structures
- requirements for evaluation of existing structures

The Highway Structures Design Guide (1) provides comprehensive design requirements for the following types of highway structure:

- bridges carrying road and/or pedestrian/cyclist traffic, in which the main supporting members are of reinforced or prestressed concrete, structural steel, timber or aluminium, utilising beam or arch action, and spanning up to 100m
- pedestrian and cyclist subways
- stock underpasses
- all culverts or multiple culverts with a total waterway area equal to or exceeding 3.4m² (major culverts)
- culverts with waterway area less than 3.4m² (minor culverts)
- retaining wall systems including gravity walls, cantilever walls, mechanically stabilised earth walls and anchored walls
- sign support structures (including those for large and overhead signs)
- ITS equipment support structures
- lighting columns and masts
- traffic signal and speed camera poles
- roadside barriers
- noise barriers

- security and safety fences and barriers
- piped stormwater system elements
- earthworks (natural slopes, embankments and cuttings), whether associated with or separate from significant structures.

The Highway Structures Design Guide (1) provides partial design requirements for the following highway structure types:

- bridges constructed of materials other than those listed above and/or having spans greater than 100m
- suspension or cable-stayed bridges
- coastal and river erosion protection works
- rockfall and debris control structures
- buildings
- tunnels
- other structures.

The Highway Structures Design Guide (1) also provides the Transport Agency's design requirements for structures that are not Transport Agency owned, but are present within the state highway road reserve.

3. Technical Approval, Review and Certification Procedures

The design and construction of highway structures and earthworks is required by the Transport Agency to comply with specific technical approval, review and certification procedures. Detailed requirements for these procedures are set out in an appendix to the Highway Structures Design Guide (1).

The procedures were developed in 2012 from previous requirements of the Transport Agency and BD 2/12 Technical Approval of Highway Structures (4) produced by Highways England. They were previously published as appendix F to the Bridge Manual 3rd edition (5).

Technical approval procedures consist of the preparation of options reports and design statements that are submitted to the Transport Agency at distinct stages in the project cycle, and acceptance of these documents by the Transport Agency. It is intended that technical approval is complete before detailed design is commenced.

Review procedures consist of the review of designs and construction by design reviewers and construction reviewers respectively.

Certification procedures require the certification of designs, design reviews, construction and construction review by those responsible.

For the purpose of these procedures, structures and earthworks are categorised according to their level of complexity. Technical approval and review requirements vary with category.

4. Documentation Requirements

The Highway Structures Design Guide (1) contains the Transport Agency's requirements for design documentation (options reports, design statements, calculations, consents, relevant correspondence and certificates), construction documentation (drawings and specifications) and handover documentation.

The requirements were assembled by extracting relevant requirements from various existing Transport Agency specifications and contract pro-formas and reviewing and revising these to ensure that the Transport Agency's actual documentation requirements for structures were reflected and made available in a single document.

In particular, the requirements for handover documentation have been clarified. Different requirements exist for minor structures and 'significant' structures. Asset management information for significant structures is required to be produced in a form that facilitates separation for structures management purposes. Design statements are required to be updated as necessary to reflect the completed structure. A new information category called supplementary as-built records replaces what was previously known as

a construction report. Handover information is required to be approved for issue by designers, constructors and construction reviewers as appropriate.

5. Building Act 2004 and Building Code Requirements

5.1 Building Act 2004 and Building Code Compliance

In New Zealand, most, if not all, highway structures are classified as *buildings* in terms of the Building Act 2004 (2), and thus compliance with the Act is required. The Act requires that all building work (work for, or in connection with, the construction, alteration, demolition or removal of a building) complies with the Building Code (3), which sets out performance criteria that building work must meet. Highway structures fall under a *building* category referred to as 'ancillary' buildings, which are exempted from some amenity provisions, but are required to comply with structural and safety related aspects of the Building Code (3).

Building Code (3) clauses B1 Structure and B2 Durability apply to all highway structures. Additionally clause F4 Safety from Falling applies to many highway structures, and other clauses may apply in some cases.

Compliance with New Zealand Building Code (3) clauses may be achieved via either "*acceptable solutions and verification methods*" or "*alternative solutions*". Acceptable solutions and verification methods are standardized approaches documented by the Ministry of Business, Innovation and Employment that are largely intended for buildings in the traditional sense. Thus many types of highway structures achieve Building Code (3) compliance via an alternative solution – such as the Bridge Manual (5).

These alternative compliance routes have in the past not always appeared to be well understood by designers or by building consent authorities in New Zealand. Thus the Highway Structures Design Guide (1) states the intended means of compliance with relevant Building Code (3) clauses for each structure type covered by the guide.

5.2 Building Consent Requirements

Building work for some, but not all, highway structures is required by the Building Act 2004 (2) to have a building consent from a territorial or regional authority. In general, building consents are required for more significant structures, such as bridges, and simple structures such as lighting and sign supports are exempt.

Again, building consent requirements for highway structures have not always been clearly understood. The Highway Structures Design Guide (1) sets out the Transport Agency's understanding of these requirements for most types of highway structure. It is emphasised that compliance with the Building Code (3) is required irrespective of whether a building consent is required

5.3 Requirements for Alterations to Structures

The Building Act 2004 (2) also contains requirements for alterations (rebuilding, repair, enlargement or extension) to structures. For most highway structures, these can be expressed as follows:

- If the structure complied with the Building Code (3) before the alterations, it should continue to comply, and
- If it did not comply, it should continue to comply to at least the same extent as it did before the alteration.

The Highway Structures Design Guide (1) sets out the Building Act 2004 (2) requirements, and notes that this means that a road structure can be extended or upgraded without triggering a requirement for the existing structure to be upgraded to new structure standards.

6. Design Requirements for New Structures

Section 5 of the Highway Structures Design Guide (1) is perhaps the core of the document, and sets out the Transport Agency's design requirements for all new highway structures. These include all design requirements, not just structural design requirements. In many cases, these requirements are largely contained in one or more existing Transport Agency documents and so the Highway Structures Design Guide (1) refers to the relevant documents, with or without supplementary text. However, some requirements are not adequately documented elsewhere, and in these cases the guide contains new standalone requirements.

6.1 General Design Requirements

Section 6.1 of the Highway Structures Design Guide (1) contains general design requirements that are expected to apply to most or all structure types. These include:

- urban design and landscape requirements
- heritage requirements
- requirements arising from statutory and other agreements
- safety in design
- inspection and maintenance requirements
- requirements for supplier designed components
- anti-graffiti requirements
- asset identification signs
- design requirements for structures during construction.

The last of these sets out a general requirement for the strength and stability of highway structures during construction. This requires designers of all structures to give consideration to strength and stability of the incomplete structure at various stages during construction and the design events to be considered, and to document these in the structure design statement. Designers are to clearly convey via drawings and specifications the assumptions made with regard to construction sequence, methodology and temporary works required and clearly outline responsibilities.

This requirement is intended to address several imperatives, including:

- the safety of construction personnel
- the safety of members of the public on adjacent carriageways and property
- continuity of service of adjacent carriageways
- the requirements of the Health and Safety at Work Act 2015 (6)
- Building Code (3) requirements
- avoidance of adverse impacts on project delivery and reputation.

6.2 Design Requirements for Specific Structure Types

The remainder of section 6 of the Highway Structures Design Guide (1) sets out specific design requirements for highway structures by type, organized as follows:

- bridges
- non-typical bridges
- subways (for pedestrians and cyclists)
- stock underpasses
- major culverts
- retaining walls
- coastal and river erosion protection works
- earthworks
- rockfall and slope debris control structures
- minor culverts
- stormwater systems
- signs and sign support structures
- ITS equipment support structures
- lighting columns and masts
- traffic signal and speed camera signs
- road safety barriers
- noise barriers
- security and safety fences and barriers
- buildings
- road tunnels
- other structures.

For each structure type, these are organized into design philosophy and non-structural design requirements, structural design requirements and intended means of Building Code (3) compliance.

The term ‘design philosophy’ is borrowed from the Bridge Manual (5) and includes such design parameters as design life and importance level. Non-structural design requirements are generally those that relate to the intended function of the structure – such as geometric and waterway requirements for a bridge.

For several of the structure types covered, the guide simply refers to existing Transport Agency documents for design philosophy, non-structural and structural requirements – for example bridges, major culverts, retaining walls and earthworks are referred to the Bridge Manual (5) and ITS equipment support structures and traffic signal and speed camera poles are referred to Transport Agency specifications ITS-01-4 Civil and Structural Requirements (7) and NZTA P43 Specification for Traffic Signals (8) respectively.

However for some structure types, the requirements in existing documents were found on examination to require supplementing. The Bridge Manual (5) was found to deal adequately with the structural requirements for subways and stock underpasses, but non-structural requirements are augmented by the guide.

Transport Agency specifications TNZ P/24 Performance Based Specification for Traffic Signs (9), NZTA M26 Specification for Lighting Columns (10), NZTA M23 Specification for Road Safety Barrier Systems (11) and NZTA P40 Specification for noise mitigation (12) for signs and sign support structures, lighting columns and masts, road safety barriers and noise barriers respectively are also augmented to varying extents by the guide.

Requirements for minor culverts and stormwater systems were found to be lacking, but are now provided by the guide and the new Transport Agency specification NZTA P46 NZ Transport Agency State Highway Stormwater Specification (13).

Requirements for security and safety fences and barriers were also found to be not addressed by existing documents, and a relatively large section has been added to the guide covering these in detail.

The Transport Agency also did not previously have documented requirements for coastal and river erosion protection works, for rockfall and slope debris control structures and for buildings in the conventional sense. Partial requirements for these have been formulated and added to the guide, with a requirement that they are supplemented and confirmed on a project-by-project basis.

Several of the 'new' design requirements are described in more detail in section 10 of this paper.

7. Requirements for Alterations to Existing Structures

The Transport Agency's requirements for alterations (including extensions or improvements) to existing structures are stated in section 6 of the Highway Structures Design Guide (1).

The guide's technical approval, review and certification procedures, documentation requirements and Building Act 2004 (2) compliance requirements apply to alteration work unless agreed otherwise with the Transport Agency.

The Transport Agency's minimum requirements for alteration of an existing highway structure are that:

- The new work complies with the requirements for a new structure set out in the guide.
- The altered structure continues to comply with the new structure requirements of the guide to at least the same extent as before the alteration.

These minimum requirements achieve compliance with the Building Act 2004 (2) as well as the agency's own requirements. The Transport Agency may seek to improve existing portions of the structure, and so the actual requirements to be adopted are to be confirmed via structure options reports and design statements.

8. Evaluation of Existing Structures

Although the Highway Structures Design Guide (1) is a "design guide", it was decided that reference would be made to the agency's requirements for evaluation of existing structures. Section 7 of the guide refers to the agency's existing document for evaluation of traffic load carrying capacity (contained in section 7 of the Bridge Manual (5)) and screening procedures for traffic load capacity risk, waterway risk and seismic risk.

9. Requirements for Non-Transport Agency Structures

Structures that are not Transport Agency owned can be present within the road reserve. Examples include rail bridges, pipe bridges and local authority bridges that cross state highways, footbridges, retaining walls

within the state highway road reserve that support rail tracks or buildings, buried structures that convey rail or materials under or alongside state highways and utility structures.

Some of these structures are entitled under legislation to be present in the road reserve. Others are present at the discretion of the Transport Agency. In some cases the Transport Agency agrees to the construction of structures within the road reserve to meet a non-highway need, but assumes ownership of the structure – stock underpasses being one example.

In all cases where others desire the construction of a structure within the road reserve, the agreement of the Transport Agency as manager and operator of the state highway network must be obtained. The Highway Structures Design Guide (1) describes and refers to the processes and procedures that apply to the obtaining of such agreements. In all cases the Transport Agency has the ability to impose or request conditions, including the design requirements, maintenance strategy and maintenance agreement for the new structure.

The guide states that for new structures, the Transport Agency shall impose any minimum design requirements necessary to ensure that the performance of the state highway is not compromised by the presence of the structure. These requirements will be additive to the owners requirements for the structure.

The minimum requirements shall include those that would apply to a Transport Agency owned structure in the same physical relationship to the state highway that derive from the proximity to the state highway. For example, a bridge over the state highway carrying rail, pipes or a local road is required to as a minimum meet the same clearance requirements, pier collision load requirements, urban design requirements and be designed for the same extreme event annual probabilities of exceedance as a Transport Agency owned bridge over the state highway.

The minimum requirements shall also include requirements that derive from the contents of or traffic supported by the structure to the extent that they pose risks to the continuing functionality of the state highway and the safety of its users. Examples are gas pipeline explosion or rail or road vehicles breaching the side protection of a bridge over the state highway.

The structure design requirements are required to be included in the structure design statement for endorsement by the Transport Agency.

10. New Design Requirements Contained or Referenced In the Highway Structures Design Guide

After the initial draft of the Highway Structures Design Guide (1) had been assembled, it became apparent that Transport Agency did not have complete and readily accessible standardized requirements for the following types of minor structure:

- subways (for pedestrians and cyclists)
- stock underpasses
- minor culverts
- stormwater systems
- traffic signal and speed camera poles and masts
- noise barriers
- security and safety fences and barriers.

Beca Ltd was commissioned to investigate and document current New Zealand practice including recent major project Principal's Requirements, current standards and guidelines and supplier standard practice for these structure types and to propose standard requirements for incorporation into the guide. The draft requirements were reviewed within the Transport Agency and/or by external peer reviewers where considered appropriate before being finalized and incorporated.

The resulting design requirements are briefly described below:

10.1 Subways

The structural requirements for subways for pedestrians and cyclists are dealt with adequately in the Bridge Manual (5) – however design philosophy and non-structural design requirements are not. Design philosophy is now required by the guide to be as for a bridge on the same route. It was found that non-structural requirements were able to be defined by reference to the Transport Agency's Bridging the Gap:

Urban Design *Guidelines* (14) and the Austroads Guide to Road Design part 6A Pedestrian and Cyclist Paths (15), supplemented as follows:

- Specific requirements for design for use by people with disabilities are given.
- A desirable minimum cover of 600mm is stated, together with backfill requirements.
- Subway minimum length requirements are given, together with associated road safety barrier requirements.
- Drainage and watertightness requirements are stated.

10.2 Stock Underpasses

As with subways, the structural requirements for stock underpasses are largely dealt with adequately in the Bridge Manual (5), and have been augmented in the guide only with regard to the durability issues posed by stock effluent and connection requirements for precast concrete units.

The guide requires a design working life of 100 years for stock underpasses and associated structures within the road reserve, with importance level taken as for a bridge on the same route.

Non-structural requirements were developed after a review of the New Zealand Road Controlling Authorities Forum Best Practice Guidelines for Stock Crossings (16) and the specific requirements of several local road controlling authorities and consideration of factors important to the Agency. The guide sets out resulting requirements for location, alignment, cover (minimum 600mm) and backfill, gradient, length, drainage, accommodation of utility services, road safety barriers and fencing.

10.3 Minor Culverts

The Bridge Manual (5) contains comprehensive requirements for so-called major culverts (culverts or multiple culverts with a total waterway area greater than or equal to 3.4m^2). However the only standardized requirements for minor culverts were found to be those in NZTA F3 Pipe Culvert Construction (17), and so requirements for design philosophy, non-structural and structural design requirements for minor culverts were formulated for the guide.

Design philosophy and non-structural requirements specifically addressing design working life and importance level, hydrology, design floods and culvert sizing criteria, fish passage and sediment transport, outlet protection, road user safety and pipe materials, and referencing the Bridge Manual (5) and Austroads Guide to Road Design part 5 Drainage – General and Hydrology Considerations (18) and part 5B Drainage – Open Channels, Culverts and Floodways (19) were drafted and peer reviewed. However rather than being incorporated into the guide, these requirements were incorporated into a new Agency specification, NZTA P46 NZ Transport Agency State Highway Stormwater Specification (13) which was published in April 2016. The Highway Structures Design Guide (1) refers to NZTA P46 (13) for these requirements.

The guide contains structural design requirements for minor culverts. For reinforced concrete and corrugated metal pipe culverts these are referenced to the Bridge Manual (5), and for other pipe materials design is required to be in accordance with AS/NZS 2566.1 Buried Flexible Pipelines part 1 Structural Design (20). Headwall and wingwall design requirements are clarified to be as given in the Bridge Manual (5).

10.4 Stormwater Systems

Requirements for design philosophy, non-structural design and structural design were formulated for the structural elements of piped stormwater systems including pipes, manholes, cesspits and associated grates and covers.

These included specific requirements for design life and importance level, rainfall depth/intensity, pavement surface drainage design criteria, collection system details, pipe network design and subsoil drainage. However with the exception of subsoil drainage requirements, these were all incorporated into NZTA P46 (13) rather than into the Highway Structures Design Guide (1), and are instead referenced from the guide.

The guide contains structural design requirements for stormwater system elements, including loading requirements.

10.5 Traffic Signal and Speed Camera Poles and Masts

The review of current practice carried out determined that the non-structural or functional design requirements for traffic signal and speed camera poles and masts were generally well addressed by existing guidelines, but that design life, importance level and structural design requirements required clarification. Accordingly draft requirements were prepared for these items. However it was determined that these would be incorporated into another new Transport Agency specification, NZTA P43 Specification for Traffic Signals (8) and accordingly the Highway Structures Design Guide (1) refers to NZTA P43 (8) for all requirements. At the time of writing of this paper NZTA P43 (8) remains in draft after undergoing public consultation.

10.6 Noise Barriers

The review of current practice carried out determined that existing Transport Agency documents NZTA P40 Specification for Noise Mitigation (12) and the NZTA State Highway Noise Barrier Design Guide (21) adequately addressed non-structural design requirements, but that design working life, importance level and structural design requirements could desirably be clarified.

This has been done within the Highway Structures Design Guide (1).

10.7 Security and Safety Fences and Barriers

Security fences and barriers are defined in the Highway Structures Design Guide (1) as being those provided to discourage, restrict or prevent access. Examples include low fences and rails, timber fences, steel mesh security fences, stock fences, deer fences and predator proof fencing. Safety fences and barriers are those provided to safeguard people from injury caused by falling.

The review of current requirements carried out determined that apart from fencing responsibilities outlined in the State Highway Control Manual (22) and the requirements for barriers on bridges, major culverts and retaining walls outlined in the Bridge Manual (5), the Agency did not have complete and standardized requirements for security and safety fences and barriers.

Particular issues identified as requiring clarification included:

- intended design life and life to first maintenance
- design loading for barriers on structures not covered by the Bridge Manual (5)
- design loading for security fences
- durability of timber fences and barriers
- requirements for provision of safety from falling barriers in ‘off-structure’ situations where members of the public are expected to be present, such as footpaths and other public areas
- requirements for provision of safety from falling barriers adjacent to paths or areas intended for use for inspection and maintenance or in emergency situations, or where members of the public may occasionally be present
- requirements for provision of bicycle path safety barriers
- the common and unsuitable use of the term ‘pool fencing’ to specify security and safety fences.

Comprehensive requirements (design philosophy, non-structural and structural) to address these issues were drafted, reviewed and subsequently augmented and are now incorporated into the Highway Structures Design Guide (1).

Reference is also made to urban and landscaping design factors, safety in design and crime prevention through environmental design.

The opportunity was taken to review and revise the safety barrier requirements in the Bridge Manual (3rd edition amendment 2) (5) at the same time so as to present a consistent set of requirements.

11. Implementation and Ongoing Development

The Highway Structures Design Guide (1) was issued for use in May 2016 (1st edition, amendment 0). Its use on Transport Agency projects will become increasingly common as contract pro-formas are updated

to refer to it and contracts for new projects are signed. It is expected that contract documents will be able to be shortened and will become more consistent, by referring to the guide for many requirements rather than documenting them on a project-by-project basis.

Just as with existing Transport Agency design documents, project-specific departures will be allowed with agreement from the Transport Agency.

It is expected that the guide will be subject to on-going development, and feedback from designers, contractors and suppliers, both on the guide itself and on the referenced documents, is welcomed. It is possible that the supplementary requirements contained in the guide for many structure types will eventually be absorbed into subsidiary documents.

12. Acknowledgement

The permission of the NZ Transport Agency to publish this paper is acknowledged.

The assistance provided by other Transport Agency staff, Opus International Consultants Ltd, the Ministry of Business, Innovation and Employment and suppliers in the review of the guide is also acknowledged.

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