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9th December 2004

To: Regional Managers, Asset Managers, Project Engineers & Manual Holders

From: Frank McGuire, Senior Roading Engineer

**SUBJECT: Bridge Manual Second Edition 2003
Amendment: September 2004**

Objective

To issue the September 2004 Amendment to the *Bridge Manual 2nd Edition 2003*.

Background

The *Bridge Manual 2nd Edition 2003* was issued in October 2003 and was updated in June 2004. This letter announces the Issue and Implementation of Amendment September 2004.

Attachments

- (i) **Commentary** – on the September 2004 Amendment.
- (ii) **September 2004 Amendment to the *Bridge Manual 2nd Edition 2003***– incorporates amendments to pages *i, ii, v* and *ix*, and to Chapters 2 to 6 inclusive, with the amendments highlighted by a vertical line at the left hand margin. Encompassed are:
 - Amendments to achieve compatibility with AS/NZS 1170 Design Structural Actions affecting Chapters 2, 3 and 6
 - Amendments to Section 4.7 Bearings to include all types of bearings and to also incorporate requirements for deck joints
 - Amendments to the requirements for foundations and for retaining structures. This has resulted in Section 4.8 being split into two separate sections, one for foundations and one for retaining structures, and also amendments have been made to Chapter 5 relating to the earthquake resistant design of foundations and retaining structures.

Update Your Copies of the Bridge Manual

Please update your copies of the Bridge Manual by removing the superseded sections and replacing them with the Sections dated September 2004. That is: pages *i, ii, v* and *ix*, and Chapters 2 to 6 inclusive.

Availability

The *Bridge Manual 2nd Edition 2003*, updated with all Amendments to September 2004, is available to view and download from the Transit Website free of charge at:

http://www.transit.govt.nz/technical_information/view_manual.jsp?content_type=manual&edit&primary_key=38&action=edit

Alternatively, a hardcopy of the *Bridge Manual 2nd Edition 2003*, with all Amendments to September 2004, may be purchased using the on-line form at:

<http://www.transit.govt.nz/jsp/order/manualorder.jsp>

or requested from:

The Publications Officer
Transit New Zealand
PO Box 5084
Wellington
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Amended Loadings for Design compared with the Current Bridge Manual

- (i) **Wind Loading** - In general, wind is not the critical load for lateral loading on a bridge. Earthquake loading usually dominates the design for lateral loads except in Auckland and Northland regions. For bridges in Auckland the design wind loading will either remain almost the same or reduce by up to about 10%, while in Wellington the design wind loading will either remain almost the same or increase by up to about 5%.
- (ii) **Snow Loading** – Snow loading is a gravity load and will not generally act with live loading. For road bridges, live load is the critical applied gravity load case, but for long-span footbridges in alpine regions snow loading may be critical. So few, if any, of these have been built that the implication of this change is insignificant.
- (iii) **Flooding Loading** – Currently, all bridges are required to be designed at the ultimate limit state (ULS) to withstand a 2,000 year return period flood event, though they may be inundated in such an event. Aligning with the probabilities of exceedance for environmental events given in AS/NZS 1170 will raise the ULS design return period to 5,000 years for the most important bridges, which are few in number and of which much fewer again are river crossings. For most state highway bridges, the return period of the ULS design event will rise to 2500 years. Unless confined by a gorge, which is unlikely for such bridges, increasing the return period of the event is likely to have little effect on the lateral loading on the bridge, affecting more the width of spread of the flood flow either side of the main river channel. On balance, the overall implications to loadings from amendments to the flood return period are expected to be relatively small.

Implementation Date

The September 2004 Amendment to the *Bridge Manual 2nd Edition 2003* should be implemented from the date of this letter with application to all new bridge design work commissioned by Transit New Zealand:

It is Recommended that Implementation apply in full to all bridges where the design statement has not been formally agreed by Transit.

Should you have any questions regarding this letter please contact Frank McGuire at Transit National Office, DDI phone number: +64 4496 6690, Email: frank.mcguire@transit.govt.nz

Please Advise

Please advise your Consultants of the above.

Yours sincerely



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Amendments are shown with a bar in the left margin. The following sets out an explanation and justification for the changes.

Introduction

Amendment September 2004 incorporates amendments to the following sections of the Bridge Manual or to various sections of the Bridge for the following aspects:

- Amendments to achieve compatibility with AS/NZS 1170 Design Structural Actions have been incorporated, affecting Chapters 2, 3 and 6
- Amendments to section 4.7 Bearings to include all types of bearings and to also incorporate requirements for deck joints
- Amendments to the requirements for foundations and for retaining structures. This has resulted in section 4.8 being split into two separate sections, one for foundations and one for retaining structures, and also amendments have been made to Chapter 5 relating to the earthquake resistant design of foundations and retaining structures.

This Commentary sets out commentary on each of these areas in turn.

Compatibility with AS/NZS 1170: Structural Design Actions

The amendments incorporated seek to achieve compatibility between the Bridge Manual and Parts 0, 1, 2 and 3 of AS/NZS 1170. Part 4 was excluded as it has yet to be finalised and published. The following sets out an explanation of, and justification for, the changes proposed.

General Philosophy

AS/NZS 1170 is written in a manner that focuses on application to buildings, but its application has not been stated to be limited to buildings. Rather the Standard is promoted as setting out general principles relevant to the design of any structure. The Standard is intended for citation by the New Zealand Building Code as an acceptable solution for design loadings. Consequently, it is possible that Territorial Authorities granting Resource Consents may seek to insist on its application to bridges, for which it is not necessarily easy to interpret, appropriate or adequate. Notably, the “Australian Bridge Design Code” is referred to as providing information useful or necessary for the design of bridges, but no reference is made to Transit’s “Bridge Manual”.

Changes to Chapter 2

Definition of Design Working Life (Clause 2.1.2)

The definition of Design Life has been reviewed for appropriateness. The Bridge Manual design life requirement of 100 years (in normal circumstances) exceeds the NZ Building Code minimum requirements. Comparison with British (120 years) and Australian (100 years) Bridge Manual requirements were undertaken. The current Bridge Manual design life requirement is considered appropriate. For consistency of terminology, *Design Life* has been amended to *Design Working Life*.

Clause 2.1.3: Basis of Design

AS/NZS 1170 Part 0 Section 3.2 and Tables 3.1 and 3.2 assign an importance level to structures and Table 3.3 corresponding annual probabilities of exceedance for wind, snow and earthquake loads. Importance level descriptions do not make reference to bridges. Thus an interpretation has been made of importance levels appropriate for bridges and this is given in Table 2.1 contained within clause 2.1.3.

As the document is expected to become cited by the *New Zealand Building Code Handbook* as an acceptable solution for design loadings, consideration has been given to the design loadings adopted by AS/NZS 1170: Structural Design Actions.

Wind, snow, earthquake and floodwater actions are all environmental actions for which it is considered similar levels of annual probability of exceedance are appropriate for bridges of similar importance. For wind and earthquake AS/NZS 1170 adopts the same annual probabilities of exceedance for structures of the same importance and design life. AS/NZS 1170 provides no explanation as to why it adopted a different probability of exceedance for snow, and no justification has been perceived for adopting a lower annual probability of exceedance than for wind. AS/NZS 1170 does not consider floodwater actions.

Annual probabilities of exceedance for the ultimate limit state (ULS) and serviceability limit state II (SLS II) have been adopted for wind snow and floodwater actions that align with the probabilities of exceedance specified in AS/NZS 1170 for wind and earthquake.

Importance Level 4 annual probabilities of exceedance have been extrapolated from the AS/NZS 1170 criteria. For State Highway bridges considered to fall within Importance Level 4, an increase in the return period for the design wind and flood water event will result. However, very few new bridges are expected to fall into this importance category.

Corresponding amendments have also been made to clauses 2.3.2 Design Floods and 3.4.5 Wind. Snow has been added as a design action, specified in new clause 3.4.11.

Snow loading, under serviceability and ultimate limit state events, will generally be exceeded by the design live load, and so snow loading does not need to be considered for road bridges. Under the ultimate limit state event, snow loading may be critical for long span footbridges in alpine regions, and so should be considered for those.

For the serviceability limit state, the annual probability of exceedance for damage avoidance (SLS II) adopted by AS/NZS 1170 for all environmental actions, importance levels and for both permanent and temporary bridges has been adopted. Operational functionality (SLS I) is only required to be considered for floodwater actions on the basis that under wind loads vehicle travel is likely to cease due to vehicle instability or driver discomfort before a bridge becomes inoperable. For floodwater actions, the existing requirements for the SLS I are retained.

Earthquake loading has not been addressed by this amendment, but will be addressed once the revised earthquake loading part (NZ 1170.5) is finalised and published.

Clause 2.1.6: Limit state Requirements

Serviceability Limit State requirements have been revised to achieve consistency with clause 2.1.3.

Clause 2.1.8: Structural Robustness

This concept has implications for design for such actions as earthquake, flood and collision in particular. Provision of structural redundancy and the ability to redistribute loads within the structure is promoted. This is contrary to common modern bridge design practice, in which simply supported spans on single column piers are widely utilised. All parts of the structure are required to be interconnected. The Bridge Manual does not require interconnection at the abutments between the superstructure and abutment if sufficient overlap of the elements is provided.

Incorporation of a requirement for the consideration of structural robustness is proposed as a new clause, 2.1.8.

Clause 2.3.2: Design Floods

2.3.2(c) and (d) have been revised to achieve consistency with clause 2.1.3.

Clause 2.7: Special Studies

Incorporation of requirements relating to special studies, encompassing justification for the study, demonstration of appropriateness of the study, confirmation of the study findings, and documentation of the study have been included (new Clause 2.7).

Changes to Chapter 3

Clause 3.4.5: Wind

The Bridge Manual currently draws on NZS 4203 for the derivation of the design wind gust speed, and then applies the provisions of BS 5400 Part 2 for derivation of the wind forces acting on a bridge.

AS/NZS 1170 now replaces NZS 4203 for the derivation of the design wind gust speed, with the added benefit that AS/NZS 1170 caters for a range of annual probabilities of exceedance appropriate to structures of differing importance and life expectancy. These changes are included (new Clause 3.4.5).

The UK approach of giving consideration to wind acting on adverse and relieving areas as presented in BS 5400 Part 2, has been adopted and incorporated. For footbridges over 30m in span, requirements have also been incorporated for the consideration of aerodynamic effects. These amendments provide a more comprehensive treatment of wind load than existed previously.

Clause 3.4.9: Ground Water on Buried Surfaces

A new Clause 3.4.9, covers requirements for the consideration of hydrostatic water pressure on buried surfaces.

A new load definition, GW - Ground Water, has been added to Clause 3.5 and Load Combination Tables 3.2 and 3.3.

Clause 3.4.10: Water Ponding

A new Clause 3.4.10, covers requirements for including the action resulting from rainwater ponding, assuming all primary outlets are blocked.

A new load definition, PW – Water Ponding, has been added to Clause 3.5 and Load Combination Tables 3.1 and 3.2.

Clause 3.4.11: Snow

A new clause, 3.4.11, covers requirements for snow loading, drawing on AS/NZS 1170.3. Because snow loading is generally less critical than live loading for bridges, snow loading need only be considered for footbridges at the ultimate limit state.

A new load definition, SN – Snow load, has been added to Clause 3.5 and Load Combination Tables 3.1 and 3.2. A new load combination has been added to Table 3.2 only covering snow in combination with other loads applied to footbridges at the ultimate limit state.

Clause 3.5: Combination of Load Effects

AS/NZS 1170 provides a more definitive specification of the consideration of stability than is currently given in the Bridge Manual. However, the stability and strength combinations given in AS/NZS 1170 are generally the same as the Bridge Manual. The existing Bridge Manual Clause 2.1.6 defines the ULS to cover both strength and stability. The note at the bottom of Table 3.2 covering removal of dead load factors for a more critical case has been amended to include all permanent loads.

As stated above new load definitions, PW (Water Ponding), GW (Ground Water) and SN (Snow Load) have been added to Clause 3.5 and Load Combination Tables 3.1 and 3.2, and a new load combination added to Table 3.2.

Changes to Chapter 6

Proof Load Testing

AS/NZS 1170 indicates that the target test load for the limit state being examined should be applied for at least 15 minutes. This concept is incorporated into the Bridge Manual, to allow for time dependent movements. The requirement is added to Clause 6.6.3 and applied to final loading only to minimise potential delays during road closures.

Bearings

General Philosophy

Up until now, the Bridge Manual has contained only limited criteria for bearings, requiring only that elastomeric bearings comply with AS 1523 or BE 1/76 and be generally chosen from those commercially available, and that bearings be designed to be replaceable.

Bearings are recognised as being one of the components of bridges most responsible for incurring maintenance costs. Internationally, design codes and bridge authorities have placed increasing emphasis on bearings, developing criteria for their use and design, with codes devoting significant sections to their specification.

In particular, in North America and the UK, the trend is towards eliminating bearings wherever possible and making the bridge structures integral. In these countries, corrosion of metal bearings will have been a particular problem due to the use of de-icing salts on their roads. Taking this approach is not considered to be appropriate in New Zealand, where we have a highly developed precast concrete industry and extensive use is made of precast elements in bridge superstructures. Supporting these elements on bearings has provided a

popular, convenient and economical solution in New Zealand bridge construction. Most New Zealand bridge construction uses relatively short spans, allowing elastomeric bearings to be used, and resulting in problems of corrosion of critical bearing components being minimal.

In this revision, particular focus has been placed on harmonising with Australian practice where possible, and on ensuring the robustness of bearings to the response of bridge structures to earthquakes.

Changes to Chapter 4

Section 4.7: Bearings and Deck Joints

AS 5100: 2004 Bridge Design presents extensive criteria for the design of bearings, and, in general, these are considered to appropriate and their adoption is proposed. Where necessary, amendments to the AS 5100 criteria are proposed to suit local conditions. Design loads are defined consistent with those specified in Section 3 of the Bridge Manual.

Adoption of the AS 5100 criteria and the application of criteria for elastomeric bearings is given in clause 4.7.1. Amendments to the AS 5100 criteria and additional criteria are given in clause 4.7.2.

The AS 5100 standard adopts criteria for the design of elastomeric bearings with significant differences to those presented in AS 1523 or BE 1/76, which, in the past, have provided satisfactory performance. Adoption of the AS 5100's elastomeric bearing design criteria is not proposed until a detailed study can be undertaken to identify the effect and significance of the differences. It is understood that there is considerable dissension within the elastomeric bearing industry over what criteria are appropriate for the design of elastomeric bearings, and that revision of AS 1523 has failed to eventuate because of this. Maximum permitted shear strains, not previously specified, are proposed for both normal service conditions and under response to earthquake.

Experience from past large earthquakes has demonstrated bearings to be particularly vulnerable to damage in such events. A number of criteria are proposed, aimed particularly at ensuring the robustness of bearings and their fixings to earthquake loading.

Deck Joints

General Philosophy

Studies have shown that deck joint deterioration is the most common maintenance problem affecting New Zealand road bridges. Deck joints are also a potential source of deterioration to the bridge structure itself where leaking joints can promote corrosion of underlying structural elements.

There is currently only minimal guidance for design, selection and installation of deck expansion joints in the Bridge Manual and the aim of this amendment is to upgrade the design guidance for deck joints.

This amendment is based around adoption of AS 5100.4 - 2004 Bridge Design , Part 4: Bearings and Deck Joints with some modifications to reflect New Zealand specific practice and conditions. The AS 5100 Bridge Design standard contains comprehensive requirements for deck joints which are generally complementary to those currently in the Bridge Manual.

The Bridge Manual currently considers deck expansion joints in Section 4 Analysis and Design Criteria and in Section 5 Earthquake Resistant Design.

Changes to Chapter 4

In the existing Bridge Manual, deck joints are covered in Subsection 4.12.7 Expansion Joints under Section 4.12 Miscellaneous Design Requirements. Deck joints have now been amalgamated with bearings into Section 4.7 Bearings and Deck Joints. Subsection 4.12.7 has been deleted and references to deck joint performance in Subsection 4.12.4 Deck Drainage have been incorporated into the new Section 4.7.

In the revised section 4.7 deck joints are covered under 4.7.1 General, 4.7.3 Modifications to the AS 5100: Bridge Design, Part 4: Bearings and Deck Joints Criteria for Deck Joints and 4.7.4 Additional Criteria and Guidance for Deck Joints.

Subsection 4.7.1: General

Clause 4.7.1 (c) covers the requirement to minimise the number of deck joints in a bridge and, in some circumstances to consider the use of integral abutments. This approach follows the international trend towards the elimination of deck joints by making the bridge superstructure continuous wherever possible to avoid problems associated with deck joints. In drafting this clause, reference was made the approach taken in UK Department of Transportation BA 42/96 The Design of Integral Bridges.

Subsection 4.7.3: Modifications to the AS 5100: Bridge Design, Part 4: Bearings and Deck Joints Criteria for Deck Joints

A fundamental change to the AS 5100 Bridge Design standard requirements is the need to accommodate the effects of earthquake movement on deck joint performance. The effects of earthquake are considered in clauses 4.7.3 (a) and 4.7.3 (c) in terms of the maximum open gap and movement at the ultimate limit state.

In clause 4.7.3 (b) the design loads have been modified to be in accordance with New Zealand practice and nomenclature. An impact factor of 1.6 has been adopted in accordance with the AS 5100 standard to account for the high dynamic loads on deck joints.

A significant change is to the anchorage of deck joints. In clause 4.7.3 (d), deck joints attached by bolts cast into a concrete substrate the bolts are required to be fully tensioned high tensile bolts rather than lower grade bolts tightened to a percentage of their proof load. This in turn removes the requirement to consider fatigue of the anchors.

A critical performance requirement for deck expansion joints and associated hardware is the control of deck drainage water. An unexpected finding of Transfund Research Report No.186 Performance of Deck Expansion Joints in New Zealand Road Bridges was the continued use of open deck joints. Clause 4.7.3 (e) requires that deck joints are watertight and recommends the use of sealed expansion joints. Where open joints are used they are required to include a separate drainage system to collect and dispose of the water which will not be damaged as a consequence of earthquake movement.

Additional requirements for deck joint installation (clause 4.7. (e)) pertain particularly to the timing of deck joint installation. Otherwise, the process of deck joint installation is closely related to the type of joint being installed and it is recommended that the joint suppliers be responsible for their installation.

Subsection 4.7.4: Additional Criteria and Guidance for Deck Joints

This subsection has been added to address some of the deficiencies and performance issues that have been encountered with deck joints in New Zealand.

In clause 4.7.4 (a) the critical factors in designing and selecting appropriate joint types are addressed. This clause requires the design engineer to consider both movement capacity and performance history to determine the suitability of a joint for a particular installation. Useful references are provided to give guidance on both these factors. As a performance measure proprietary deck joint suppliers are required to provide a warranty on the serviceability of their joints for a period of five years after installation.

Clause 4.7.4 (b) considers joint sealing elements and is broadly similar to the requirements of the AS 5100 Bridge Design standard. A principal requirement is that joint sealing elements must be readily replaceable as they are unlikely to achieve the design life of the bridge. Key changes include definition of the different joint sealing elements and consideration of the decompression of compression seals due to concrete creep shortening.

The clause also includes specific design requirements for poured sealant joints.

Clause 4.7.4 (c) describes the design requirements for a concrete nosing at the location of the deck joints.

Asphaltic plug joints are considered in clause 4.7.4 (d). These joint types have a good performance history when designed with suitable dimensions and applied in appropriate situations. Failures have been recorded where joint dimensions were inadequate and where rotation of the bridge deck ends under traffic loads has not been accounted for. This clause specifies measures to avoid such failures. In retrofit situations, where the joint dimensions are less than those specified, proof of performance history with a similar joint configuration is required.

Changes to Chapter 5

Deck expansion joints are currently considered under Section 5.5 Structural Integrity and Provision for Relative Displacement, subsection 5.5.1 Clearances. No changes have been made to this subsection.

Load Limiting Devices, and Shock Load Force Transfer Devices

Load limiting devices are a common feature in New Zealand bridge designs and on occasion shock load force transfer devices have also been adopted. They are usually adopted as part of the approach to the earthquake resistant design of the structures. These devices include abutment “knock-off” elements, deck joint “knock-up” elements, base isolation mechanical energy dissipating systems, and shock load force transfer devices (e.g. the Colebrand devices as installed on the SH1 Clarence River bridge). Up until now, except for mechanical energy dissipating devices, criteria for the design of these elements has been lacking in the Bridge Manual. Criteria are now included, and are presented in clause 4.12.6.

Foundations and Earth Retaining Structures

General Philosophy

The section on foundations has been amended to better reflect ultimate limit state and load and resistance factor design approach used for the structural members of highway structures.

The sections have also been updated to include references to recent standards and codes of practice. The strength reduction factors in the Manual have been reviewed and amended to take account of current methods of analyses, testing and the variability in conditions and level of redundancy common for highway structures, and the performance expectations for such structures in New Zealand. It also covers more explicitly the need to consider the effects of earth deformation on the structure.

The Bridge Manual has so far had not covered retaining walls adequately. A variety of types of retaining structures have been introduced to the industry and retaining walls are used more extensively as highway structures, not only for abutments but also for supporting roads. The retaining wall section has been upgraded significantly to introduce different broad types of structures and their performance requirements. In particular it covers anchored structures and reinforced soil structures.

The sections also cover the design of foundations and retaining walls for earthquake performance. In particular this includes requirements for retaining structure performance and introduces displacement-based design.

The Bridge Manual requirements have been based on Transit's expectations in terms of performance of highway structures, rather than based on the acceptability of individual proprietary systems.

Changes to Chapter 3

Earthquake

Clause 3.4.3 has been amended to take into account the potential effects of vertical earthquake motions. It has become apparent from recent earthquakes and research that vertical motions can have an important effect on performance of retaining walls.

Settlement, Subsidence and Ground Deformation

Clause 3.4.13, renumbered 3.4.16, has been amended to require consideration of the effects of subsidence and ground deformation from various hazards. Subsidence from liquefaction or other reasons can have an important effect and can induce additional loads on the structure, and this needs to be taken into consideration.

Changes to Chapter 4

Section 4.8 has been split into two separate sections, one for Foundations (4.8) and one for Earth Retaining Structures (4.9) to accommodate more detailed requirements for these two specific aspects.

Loads on Foundations

Clause 4.8.1 has been amended to remove reference to working stress design and a requirement to consider downdrag forces has been added. Design based on ultimate limit state is the generally accepted approach and also is the basis of the acceptable solutions given in the BIA verification methods. Downdrag forces are important particularly in liquefaction and this clause has been clarified to ensure that this is taken into consideration.

Design Standards

Clause 4.8.2: References to overseas standards have been clarified to make users aware of useful current standards that give detailed guidance on practice. Also that the Bridge Manual takes precedence has been clarified.

Strength Reduction Factors for Foundation Design

Clause 4.8.3 has been amended to update strength reduction factors. Working stress parameters removed to tie in with Building Code. A greater number of factors have been incorporated to better reflect the level of information available for foundation design.

Foundation Capacity Determination

Clause 4.8.4 has been amended to require foundation capacities to be assessed during design and confirmed during construction. This will reinforced the need for foundation capacities to be confirmed during construction given the potential variability of ground conditions across sites, and the current common practice not to carry out site investigations at each pile / pier position.

Confirmation of Foundation Conditions During Construction

Clause 4.8.5: Requirements for confirmation of foundation capacity during construction and for pile integrity testing have been incorporated. Acceptable practices are specified for confirming foundation capacity during construction, including use of static and dynamic pile load tests. Where pile integrity tests may be required to confirm shaft integrity has been specified.

Design Standards

Clause 4.9.2 presents advice on recent retaining wall standards and guidance documents to make designers aware of useful current standards that give detailed guidance on practice. That the Bridge Manual takes precedence has also been clarified.

Factors of Safety

Table 4.3 has been amended to clarify that displacement is not acceptable under static loads.

Common Highway Retaining Structures

Clause 4.9.4 outlines the different types of retaining walls in current use so that specific requirements in subsequent new sections are meaningful.

Gravity and Reinforced Concrete Cantilever Walls

Clause 4.9.5 sets specific requirements for gravity / cantilever walls and allows the adoption of displacement-based design.

Anchored Walls

Clause 4.9.6 sets specific requirements for anchored walls. The requirement for ductile performance is clarified. Durability of anchors and corrosion protection is specified with a flow chart for selection of level of protection. Testing requirements are specified to confirm performance.

Soil Nailed Walls

Clause 4.9.7 sets specific requirements for soil nailed walls. Soil nailed walls are increasingly used and this section has been included to provide specific requirements.

Reinforced Soil Walls

Clause 4.9.8 sets specific requirements for reinforced soil walls. A variety of reinforced soil walls have been introduced to the NZ construction industry and this section provides generic requirements by reference to adequate standards and performance requirements.

Design of Embankments and Approach Cutting, and Natural Ground Instability

Clause 4.10.1: Editorial changes have been made to 4.10.1(a). In 4.10.1(b), specific requirements have been included to ensure adequate embankment design. Measures are included to improve performance and monitoring. 4.10.1(c) has been amended to ensure design addresses performance needs. Mitigation of natural hazard risks is tied to the road network performance requirements. In 4.10.1(d), requirements have been added to ensure that bridge design takes into consideration loads from embankment deformation.

Reference to the factors of safety given in 4.10.1 has been added to 4.10.2 and 4.10.3

Changes to Chapter 5

Liquefaction

A new section, 5.3, on liquefaction has been added to rationalise the wide variation in current practice and ensure that:

- (a) designers take this important earthquake ground issue into account;
- (b) the assessment uses recognised consistent methods; and
- (c) liquefaction hazards are mitigated rationally based on the expected level of service for the road.

Structure on Pile/Cylinder Foundations

Clause 5.5.6: 5.5.6(a) has been clarified to ensure that designers take into account the soil stiffness non-linearity and degradation in carrying out structural analyses. 5.5.6(b) has been revised to ensure that the consequences of liquefaction (e.g. down-drag on piles, loss of lateral support) are taken into account in the design of the piles supporting highway structures.

Structure on Spread Footing Foundations

Clause 5.5.7 has been amended to require foundations to be considered under the combined actions of static and earthquake loads.

Structure on Rocking Foundations

5.5.8(c) has been amended to require consideration of the potential for strength and stiffness of the foundation to degrade.

Earth Retaining Structures

In clause 5.7.1(a), the statement that vertical accelerations may be neglected has been removed. Recent research and observations in earthquakes has shown that vertical accelerations could have an important effect on retaining wall performance. Also, "Peak

Acceleration” has been changed to “Design Acceleration” as the formula from NZS 4203 does not give peak ground acceleration, but rather a reduced acceleration for design.

Earth Pressures and Structure Inertia Forces

Clause 5.7.2: In clause 5.7.2(a), calculation of earthquake earth pressures has been referred to a Transit New Zealand research bulletin. This clarification is to ensure that design takes into consideration the fact that the earthquake earth pressure depends on the flexibility of the wall, and specifies use of a generally accepted RRU Bulletin. An editorial change has been made to 5.7.2(b).

Design Performance

Clause 5.7.3: In 5.7.3(a) a section has been added on the performance requirements for walls designed for permanent displacement in earthquakes. Design to allow permanent displacement can be an attractive option for walls in high seismicity areas. This clause stipulates requirements to ensure adequate performance. The required design performance of abutment walls is clarified in 5.7.3(b). This clarification is provided to ensure that displacement of abutment walls is not acceptable, except where specifically justified and approved by Transit. In 5.7.3(d), the need for ductile design of anchored walls is clarified. Design shall prevent brittle failure and shall ensure ductile performance by yielding of anchors. In 5.7.3(e), displacement based design requirements for MSE walls included. These requirements also aim to ensure ductile behaviour through use of capacity design principles. References providing guidance have been included.