6 FOUNDATIONS

6.1 SCOPE

The Ministry is now using Limit States Design for foundation design versus the Working Stress Design method that has been utilized until 2006.

Commentary: *Limit States Design provisions for foundation design and geotechnical work in CAN/CSA-S6-00 have not been rigorously tested in actual bridge designs in BC. The Ministry urges designers to use caution in applying these new provisions if they result in designs that substantially deviate from the solution provided by traditional working stress methods.*

6.6 RESISTANCE AND DEFORMATION

6.6.2 Ultimate Limit State

6.6.2.1 Procedures

Delete the **Deep Foundations - Piles** section of Table 6.6.2.1 Geotechnical Resistance Factors and replace with the following:

Deep Foundations - Piles

Method	Loading	Resistance Factor
Dynamic Penetration Tests including SPT, BPT and DCPT		
	Compression	0.35
	Tension	0.25
CPT and BPT or SPT with Dynamic Monitoring and CAPWAP		
	Compression	0.45
	Tension	0.35
Dynamic Monitoring with PDA and CAPWAP; Statnamic Test		0.50
Static Load Test		
	Direction test/application reversed	0.40
	Direction test/application same	0.60
Static Load Test with separate toe and shaft instrumentation (Instrumentation details and number of test shall be consented to by the Ministry)		0.70
Horizontal Passive Resistance		0.50

Designs shall be based on information available at the time of design and higher resistance factors may not be used based on the intent to do load testing or dynamic monitoring during construction.

6.7 SHALLOW FOUNDATIONS

6.7.3 Pressure Distribution

6.7.3.4 Eccentricity Limit

Delete and replace with the following:

In the absence of detailed analysis, at the ultimate limit state for soil or rock, the eccentricity of the resultant of the factored loads at the ULS acting on the foundation, as shown in Figure 6.7.3.4, shall not exceed 0.30 times the dimension of the footing in the direction of eccentricity being considered for non-seismic load combinations, nor 0.40 times the dimension of the footing in the direction of eccentricity being considered for seismic load combinations.

Commentary: *This seismic requirement is in the Code Commentary. A study of some typical representative abutment and retaining walls configurations with typical bridge loading indicates that the Eccentricity Limits approach yields wall geometry requirements reasonably close to the traditional Working Stress design approach requiring a Safety Factor of 2.0 against overturning.*

6.8 DEEP FOUNDATIONS

6.8.5 Factored Geotechnical Axial Resistance

Add the following Clause:

6.8.5.7 Pile Load Distribution at ULS Combinations 5 and 8

Capacity design principles will be applied to the design of piles and pile caps for seismic and ship impact loads, based on assumptions for the potential upper and lower bounds of pile capacities. The number of piles and their arrangement will be based on the lower bound assumption that the piles will settle and redistribute loads to adjacent rows when piles reach their factored geotechnical capacity. The pile cap designs will be based on the upper bound assumption that the piles will not settle and will be capable of enough capacity to develop a linear elastic load distribution. For design of piles and pile caps the following shall be considered for ULS Combinations 5 and 8:

(a) Design of piles and their arrangement will be based on the assumption that when the piles reach their factored geotechnical compressive and/or tensile resistance, they will redistribute load to adjacent rows of piles within the group, and develop a “plastic” axial load distribution.

(b) Demands for the design of the pile cap elements shall be based on that assumption that the piles can develop sufficient geotechnical resistance to develop a linear elastic axial force distribution as required to resist the axial loads and moments.

Commentary: *Pile design for seismic and ship impact loads is not addressed separately in S6-00. Previous Working Stress method used increased* *allowable loads and current AASHTO LRFD methods use higher resistance factors for these load combinations. Without special treatment for these load combinations, S6-00 mandates overly conservative designs. AASHTO and ATC 49 allow for design using ultimate pile capacities (resistance factor = 1.0). However in the U.S. this is often accompanied by additional design criteria which provide a higher level of protection for structures. These can include consideration of two levels of earthquake, with a higher magnitude - lower probability earthquake, as well as specifying elastic behaviour of piled foundations. Additionally ATC 49 requires somewhat arbitrary limits on uplift of piles which can govern pile group design, and neither of these codes are specific on whether plastic or linear load distribution should be considered. Recent parametric studies indicate that using ultimate pile capacities for these load combinations may result in substantially weaker piled foundation designs than previous working stress methods.*

The methodology described in this proposed clause is consistent with the approach taken for shallow foundations in S6-00 Clause 6.7.3, and results in designs reasonably close to previous Working Stress methods. Iterative methods may be required to determine plastic axial load distributions in the piles. See Figure C6.8.5.7 (a) and (b).

6.9 LATERAL AND VERTICAL PRESSURES

6.9.2 Lateral Pressure

6.9.2.1 General

(e) The design of integral abutments shall take into account lateral earth pressure build-up and settlements in the zone of soil behind the abutments.

Commentary: *Refer to Clause 5.5.4.3 for published reference documents for design of integral abutments.*

6.9.2.2 Calculated Pressure

Seismic lateral earth pressures shall be calculated in accordance with Clause 4.6.4.

6.12 MECHANICALLY STABILIZED EARTH (MSE) STRUCTURES

6.12.2 Design

6.12.2.1 Requirements

The design shall meet the requirements of AASHTO Standard Specifications for Highway Bridges, Seventeenth Edition, 2002, including interim revisions.

For MSE bridge abutment walls and associated wing walls, the minimum soil reinforcement length provided for the portion of the MSE walls below the bridge abutments shall be 70% of the distance from the top of the leveling pad to the bridge road surface. The reinforcement length shall be uniform throughout the entire height of the wall.

For MSE retaining walls, (other than bridge abutments and associated wing walls) uneven reinforcing lengths may be used if the wall is founded on solid rock. The design shall meet the requirements of FHWA-NH1-00-043, “Mechanically Stabilized Earth Walls and Construction Guidelines”, March 2001, Section 5.3.

MSE bridge abutment walls and associated wing walls shall have precast reinforced concrete facing panels, and shall use inextensible soil reinforcing.

The maximum height for wall using extensible soil reinforcing shall be 9 m. The maximum height for MSE walls using inextensible soil reinforcing shall be 12 m.

Only MSE Wall systems listed in the Ministry Recognized Products List may be used. MSE Walls shall meet all requirements given in the Recognized Products List.

MSE walls with wire mesh facing, dry cast concrete block facing, or concrete block facing shall only be used in locations as consented to by the Ministry.

6.14 RETAINING WALLS

Retaining wall types shall meet the durability requirements and aesthetic requirements of the project and shall be subject to the 125 of the Ministry.

Design issues not addressed by S6-00 shall meet the requirements of AASHTO Standard Specifications for Highway Bridges, Seventeenth Edition, 2002, including interim revisions.

Drainage of the backfill material and all reinforced zones shall be addressed in the design of the walls and details shall be shown on the Plans.