EMBANKMENT SETTLEMENT CRITERIA FOR DESIGN

July 2 2010

SUBJECT: **EMBANKMENT SETTLEMENT CRITERIA FOR DESIGN**

PURPOSE: To provide direction and generic criteria for post construction settlements for new embankments, transitions, and for embankment widenings. The criteria are intended to provide guidance in developing targets for embankment performance during the design phase. The criteria should be reviewed and designs customized on a project specific basis.

BACKGROUND: An embankment refers to the materials placed within the side slopes, below subgrade, and above the original ground, excavated base or theoretical bottom as identified during design.

Embankment settlements are attributable to movements and changes that occur within the underlying native soils due to embankment loading. Settlements can also occur within the embankment fill.

The main types of settlement of native soils include:

1. Elastic compression
2. Primary consolidation
3. Secondary consolidation (creep)

The total settlement is the sum of these settlements.

The magnitude of these settlements is a function of the applied loading, the thickness of the compressible layer and the physical, mechanical and compressibility properties of the soil.

Elastic compression is distinguished from primary consolidation and secondary consolidation in that the settlements are immediate in nature occurring during the construction period or shortly thereafter. Primary and secondary consolidation settlements are time dependent.

Settlements within the embankment fill can occur due to its own weight. Care must be taken to properly compact embankments to reduce settlements associated with fill density changes. Settlements within granular fills generally occur during construction. Settlements within cohesive fills are time dependent and can occur following construction.

Settlements in rock fill can occur due to weathering, particle breakage and particle reorientation. These settlements are partially elastic and partially time dependent.

Differential settlement between any two points is the primary concern when assessing embankment settlement performance. When differential settlements exceed limits as governed by the flexibility of the pavement structure, asphalt cracking and distortions will occur. Differential settlement limits are required to ensure adequate transitions and to avoid unacceptable surface distortions.

Generic performance criteria for highway embankments, including asphalt pavement and slopes, are necessary to ensure safety, rideability and to optimize initial construction and post construction maintenance cost. Performance requirements will also improve provincial design consistency and provide general guidance for foundation engineers. Due engineering diligence is required to define the embankment performance criteria during detail design and to customize the selection on a project specific basis. The requirements for major highways are more stringent than secondary highways or roadways.

For the purpose of establishing settlement design criteria, the following Pavement Design Life has been assumed:

- 20 years following the construction of the pavement structure for King's highways,
- 15 years following the construction of the pavement structure for secondary highways, and
- 15 years following the construction of embankments beneath surface treated and gravel surfaces.

During detail design, the designer shall recognize that post construction maintenance such as milling and shaving and paving can be carried out before the end of design life

This document does not apply to structures. For structures, refer to the applicable design requirements of the Canadian Highway Bridge Design Code (CAN/CSA-S6-00).

POLICY:

Section 1: Settlement Design Criteria

Gravel shoulders of paved or surface treated roads can be readily restored to design crossfall by grading/addition of gravel. For paved and surface treated roads, the settlement criteria apply only to the paved or surface treated portion of the road. Designs shall account for the loss of shoulder width due to settlement and subsequent restoration of the road to design profile, by including an overbuilding of the embankment where appropriate.

1.1 New Embankments

Maximum permissible post-construction settlements for new embankments are provided in Table 1.1. Refer to Figure 1.

Total settlements are defined relative to both the longitudinal profile of the traffic

lanes of the roadway, and transversely across the top of the roadway surface.

Differential settlement rates are also applicable to both the longitudinal and transverse directions across the top of the roadway.

Table 1.1: Post-Construction Settlement Criteria For New Embankments

	Maximum Limits During Pavement Design Life	
	Total Settlement (mm)	Differential Settlement Rate
Non-Compressible Soils	50	200:1
Freeways on Compressible Soils	100	200:1
Non-Freeways On Compressible Soils	200	100:1
Surface Treated and Gravel on Compressible Soils	300	50:1

The values in Table 1.1 are recommended maximum permissible values for settlements. Each embankment shall be designed to satisfy these maximum values. Alternative foundation designs shall be developed and compared based on the advantages, disadvantages, costs, and risk/consequences. Alternatives that exceed the maximum settlement values should be considered when the initial construction costs of the alternatives are high, compared to the cost of surface repairs to correct the longitudinal and transverse profile of the surface. Typically, the embankment design selected shall be the preferred alternative that satisfies the maximum settlement values and is the most cost effective, considering both initial construction and anticipated maintenance costs.

1.2 Transition/Tapers

A smooth transition between elements such as a bridge abutment, existing embankment or other structure constructed on non-compressible soils and the new embankment shall be taken into consideration during design. The transition point is the point where an element that will have post-construction settlement intersects an element that will not have post-construction settlement. Refer to Figure 2.

In order to control the differential settlements both in the longitudinal and transverse directions between different ground treatment areas such as areas of compressible soils adjacent to areas of non compressible soils and also to afford acceptable transitions in areas of backfill and approach embankments to structures in areas of compressible soils consideration has to be given to transitions in these areas. Accordingly, embankments adjacent to bridge/culvert structures or to different ground treatment areas shall be designed with appropriate transitions and tapers in the longitudinal direction.

The total and differential post-construction settlement limits are shown in Table 1.2. The designer shall consider these limits and the varying profile grade to design an appropriate transition.

The settlement at structure/embankment interface shall not create any abrupt step deeper than 5 mm

Table 1.2: Post-Construction Settlement Criteria for Transitions

	Maximum Limits During Pavement Design Life			
Distance From Transition Point	0-20 m	20-50 m	50-75 m	>75 m
Freeways	25	50	75	100
Non-Freeways	25	50	100	200
Surface Treated and Gravel	25	75	150	300

1.3 Embankment Widening

Post-construction settlement of the widened embankment shall comply with the limits in Table 1.3. Refer to Figure 3. The differential settlement rate is applicable to both new widened embankment and also the differential settlement rate between the existing and the new embankment.

Table 1.3: Post- Construction Settlement Criteria for Embankment Widening

	Maximum Limits During Pavement Design Life	
	Total Settlement (mm)	Differential Settlement Rate
	50	200:1

Freeways		
Non-Freeways	75	100:1
Surface Treated and Gravel	100	50:1

The settlement across the widened embankment shall transition uniformly from the widening point (existing highway embankment rounding) to the new embankment rounding such that surface drainage is not impeded.

Section 2: Other Considerations

The design, construction and maintenance of embankments must ensure that post-construction deformations do not at any time:

- impair or compromise pavement support; or
- cause pavement to exceed, or fail to satisfy the pavement performance requirements

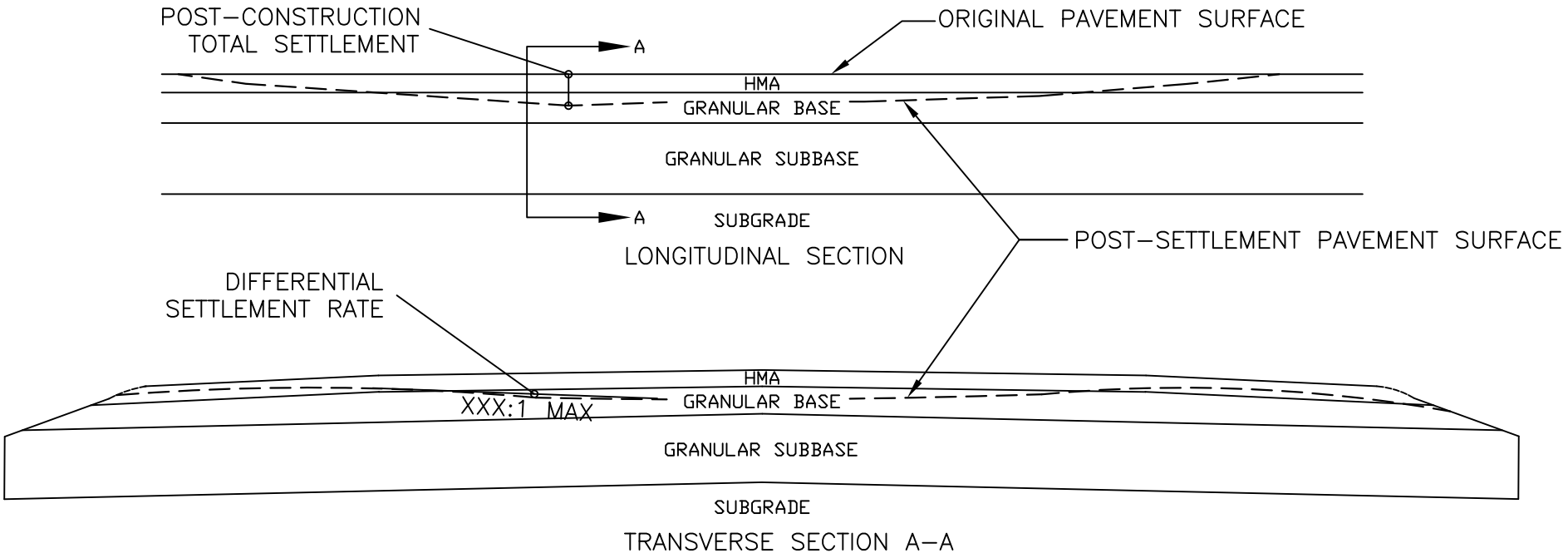
Where rigid (concrete) pavement is designed or possible by contract alternative bidding, the embankment settlement shall not result in joint faulting greater than slight (Reference Ministry of Transportation Manual for Condition Rating of Rigid Pavements, SP-026 (1995), and OPSD 551.010).

Any movement must not cause the cross-section profile to deform to an extent that would compromise surface runoff and subsurface drainage.

Embankment settlements and lateral movements of the subsoils must not adversely impact on existing structures, earthworks or services in a manner that compromises the serviceability and/or structural integrity of the existing structures, new structures, earthworks or services.

Refer to the project specific Foundations Engineering terms of reference for details regarding embankment settlement analysis and parameters for design.

Instrumentation to monitor settlement is generally required where the foundation conditions are high complexity and/or for construction safety purposes. Typically, monitoring of post-construction settlement is by observation. Where a problem is suspected, a ground survey and comparison with as-constructed elevations may be carried out.



NOTES:

1. SETTLEMENT DESIGN SHALL MEET THE TABULATED LIMITS.
2. FOR PAVED AND SURFACE TREATED ROADS, LIMITS SHALL APPLY ONLY TO THE PAVED OR SURFACE TREATED PORTION.
3. POST–CONSTRUCTION SETTLEMENT PERIODS ARE:
   - 20 YEARS FOR KING'S HIGHWAYS AND FREEWAYS
   - 15 YEARS FOR SECONDARY HIGHWAYS (500 SERIES AND HIGHER NUMBERED HIGHWAYS)
   - 15 YEARS FOR SURFACE TREATED AND GRAVEL HIGHWAYS

	SETTLEMENT LIMITS	
	TOTAL (mm)	DIFFERENTIAL
EMBANKMENT ON NON–COMPRESSIBLE SOILS	100	200:1
FREEWAYS ON COMPRESSIBLE SOILS	100	200:1
NON–FREEWAYS ON COMPRESSIBLE SOILS	200	100:1
SURFACE TREATED AND GRAVEL ON COMPRESSIBLE SOILS	300	50:1

NOT TO SCALE

SETTLEMENT DESIGN CRITERIA

NEW EMBANKMENTS

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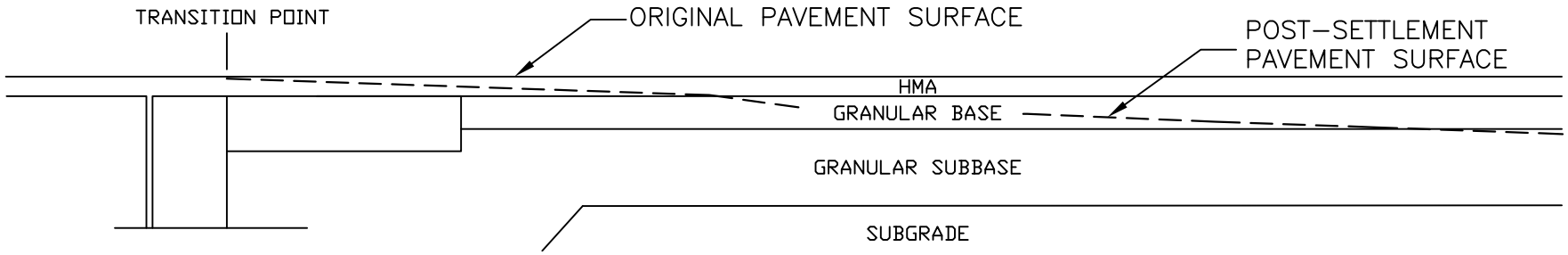
FIGURE 1



LONGITUDINAL SECTION

NOTES:

1. POST–CONSTRUCTION SETTLEMENT IN TRANSITION ZONE SHALL NOT EXCEED THE TABULATED LIMITS.

2. CRITERIA FOR TOTAL AND DIFFERENTIAL SETTLEMENT SHALL NOT EXCEED LIMITS IN FIGURE 1.

3. THE TRANSITION POINT IS THE POINT BETWEEN TWO DIFFERENT GROUND TREATMENT ZONES, INCLUDING STRUCTURE ZONE.

4. FOR PAVED AND SURFACE TREATED ROADS, LIMITS SHALL APPLY ONLY TO THE PAVED OR SURFACE TREATED PORTION.

5. POST–CONSTRUCTION SETTLEMENT PERIODS ARE:
   - 20 YEARS FOR KING'S HIGHWAYS AND FREEWAYS
   - 15 YEARS FOR SECONDARY HIGHWAYS (500 SERIES AND HIGHER NUMBERED HIGHWAYS)
   - 15 YEARS FOR SURFACE TREATED AND GRAVEL HIGHWAYS

	SETTLEMENT LIMITS (mm)			
DISTANCE FROM TRANSITION POINT	0–20 m	20–50 m	50–75 m	> 75 m
FREEWAYS	25	50	75	100
NON–FREEWAYS	25	50	100	200
SURFACE TREATED AND GRAVEL	25	75	150	300

POST–CONSTRUCTION SETTLEMENT LIMITS

LONGITUDINAL TRANSITIONS

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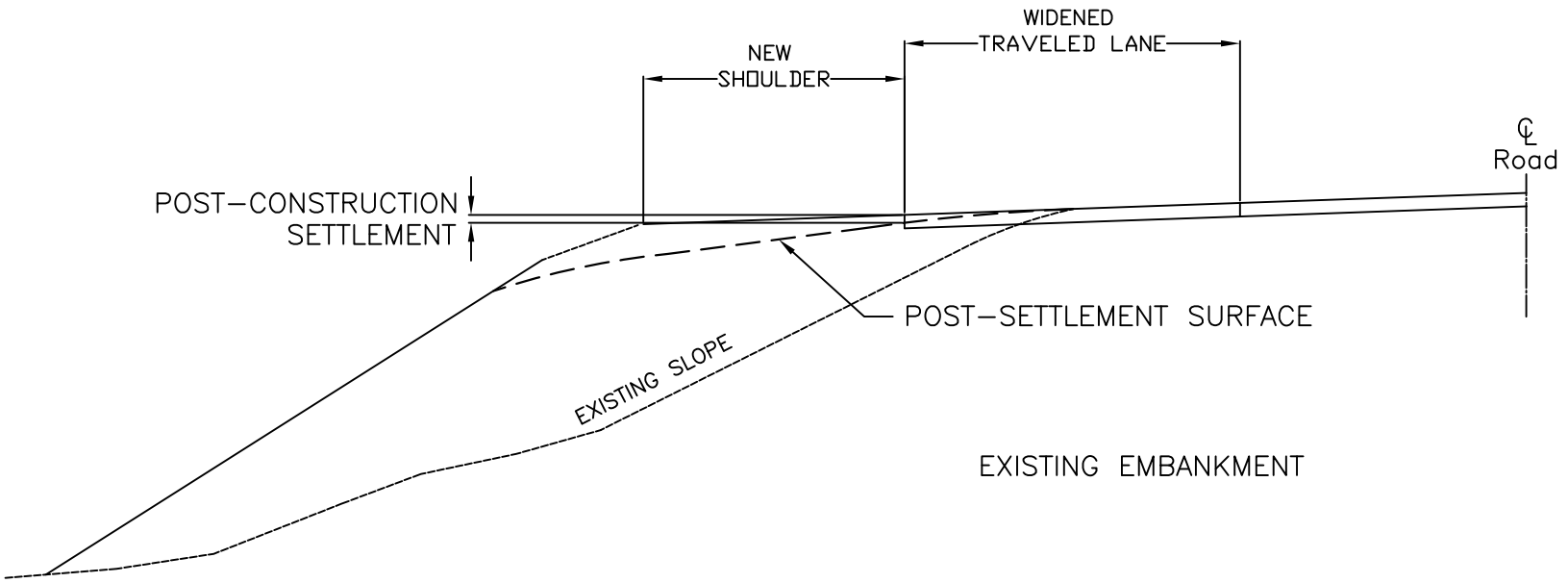
NOT TO SCALE

FIGURE 2



NOTES:

1. POST–CONSTRUCTION SETTLEMENT SHALL NOT EXCEED THE TABULATED LIMITS.

2. LIMITS SHALL APPLY ONLY TO PAVED PORTION OF ROAD.

2. POST–CONSTRUCTION SETTLEMENT PERIODS ARE:
   - 20 YEARS FOR KING'S HIGHWAYS AND FREEWAYS
   - 15 YEARS FOR SECONDARY HIGHWAYS (500 SERIES AND HIGHER NUMBERED HIGHWAYS)
   - 15 YEARS FOR SURFACE TREATED AND GRAVEL HIGHWAYS

	SETTLEMENT LIMITS	
	TOTAL (mm)	DIFFERENTIAL
FREEWAYS	50	200:1
NON–FREEWAYS	75	100:1
SURFACE TREATED AND GRAVEL	100	50:1

NOT TO SCALE

POST–CONSTRUCTION SETTLEMENT LIMITS

EMBANKMENT WIDENING

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FIGURE 3