California High-Speed Rail Authority

RFP No.: HSR 14-32

Request for Proposals for Design-Build Services for Construction Package 4

Book III, Part A.1
Design Criteria Manual Changes
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Settlement assessment shall be performed for new and existing embankments with particular emphasis on the following critical areas:

- Approaches to bridge abutments
- Soft and organic layers beneath the embankment

The vertical settlement of an embankment (which also affects overlying trackbed structure) is a combination of the permanent settlement of the foundation on which it is resting, plus permanent settlement of the embankment fill, and elastic and plastic deformations due to dynamic and repeated loading of the high-speed trains as depicted on Figure 10-1. Conventional settlement analyses shall consider ‘immediate’, ‘consolidation’, and ‘secondary’ components of settlement against the requirements of the CHSTP. For analysis of embankments, calculation procedures in the following references shall be used to assess soil settlement:

- Soil Slope and Embankment Design Manual, chapters 4 and 8, FHWA-NHI-05-123, 2005

**Figure 10-1: Settlements of Embankments**

Notes:

Reference: Figure no. 21 of UIC-719R (2008)

Geotechnical evaluations for embankments and their foundations shall include the settlement contribution from surcharge/track load, prepare subgrade, high-speed train induced vibration, and additional loading and/or ground deformation due to earthquakes.

Once the embankments are designed based on safe bearing pressures and satisfying stability and constructed in the field, the ‘residual’ settlement estimates and differential settlements
between locations along the length of the embankments shall be evaluated and estimated through track-earth-structure interaction analyses by the Geotechnical Designer.

### Table 10-5: Maximum Residual Settlement Limits

<table>
<thead>
<tr>
<th>Residual Settlement (1)</th>
<th>Non-Ballasted Track</th>
<th>Ballasted Track (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Settlement (2),(3)</td>
<td>≤ 3/8 inch</td>
<td>≤ 3/4 inch</td>
</tr>
<tr>
<td>Uniform Settlement (3)</td>
<td>≤ 5/8 inch</td>
<td>≤ 1-1/8 inch</td>
</tr>
</tbody>
</table>

Notes:

(1) Embankment shall be instrumented and monitored for a period such that the embankment and prepared subgrade-induced settlement levels off following completion of the structure. The Geotechnical Designer shall demonstrate future compliance with the residual settlements in Table 10-5 by extrapolation from the monitored data.

(2) Differential settlement shall be measured along the track (surface profile uniformity) in the vertical plane of each rail at the mid-point of a 62-foot long chord.

(3) For Service 1 and OBE load cases.

(4) For ballasted track, rail geometries will be maintained to meet FRA’s guidelines as per normal maintenance.

Embankments shall be designed and constructed so as not to exceed the maximum residual settlement set forth in Table 10-5. "Residual" settlements occur over the design life after the track is laid and shall meet these criteria. Geosutures shall be instrumented and monitored for a period such that the embankment and prepared subgrade-induced settlement levels off following completion of the structure (i.e., embankment fill and prepared subgrade are in place). Instrumentation shall remain in place and functioning properly for the Track contractor. The Geotechnical Designer shall demonstrate future compliance with the residual settlements (i.e., defined as settlements that are the sum of the remaining native foundation settlement and secondary embankment consolidation settlement estimated to occur after completion of embankment construction plus elastic and plastic deformations from dynamic train loading) by comparison of the monitored data and predicted settlement. These residual settlements are developed generally based on maintenance, passenger comfort, and track safety requirements. The residual settlements will be field verified by the Track Contractor.

If the predicted differential settlements are excessive and exceed track profile tolerances, then embankment designs shall be modified and ground improvement designed if needed to act as a foundation system. Where predicted settlements and their duration are excessive, consideration shall be undertaken to change the design from an embankment to an aerial structure or other structure.

Settlement of earth structures is time-dependent and will vary by segment. The time duration of the “waiting (leaving) period” such that the embankment/prepared subgrade-induced settlement levels off shall be evaluated and established. This period shall not be greater than the 4 month monitoring period after completion of the fill embankment and prepared subgrade.

Upon the embankment/prepared subgrade-induced settlement leveling off, the Contractor shall cover/protect the completed prepared subgrade with asphalt concrete (AC).
An illustration of various settlement parts related to time is depicted on Figure 10-2. To meet CHSTP design and performance requirements, a settlement survey program shall be developed and then implemented by the Track Contractor to monitor settlement at the “acceptance check” timeframe after laying track, and then the long term ‘residual’ settlement as part of the track maintenance program.

**Figure 10-2: Different Settlement Parts by Time**

- **Notes:**
  - Reference: Figure no. 22 of UIC-719R (2008)
  - Commentary: Per UIC 719R section 2.10.2.2 - Elastic vertical displacement of earthworks under load is usually not a design criterion, as resistance of continuous supporting structure generally implies very low vertical displacement (typically 0.004 to 0.008 inches [or 0.1 to 0.2 mm] on top of supporting structure). However, design criteria may exist to limit elastic deformation to a percentage of deformation of track components to manage the global track stiffness.
  - **Symbols:**
    - \( S_{EL} \) = Embankment Settlement at the End of Waiting Period
    - \( S_{UL} \) = Native Ground Settlement at the End of Waiting Period
    - \( S_{V} \) = Settlement due to Traffic
    - \( S_{ER} \) = Embankment Settlement During and After Installation of Tracks
    - \( S_{UR} \) = Natural Ground Settlement During and After Installation of Tracks

### 10.9.3.1 Track Subgrade Settlement Analysis

Track subgrade settlement analysis, using finite element methods such as ADINA, ABAQUS, ANSYS, PLAXIS, etc., shall be performed to estimate track-subgrade settlements as a result of dynamic loading of the high-speed trains. Limiting values are presented in Section 10.14.3.1 for ballasted and non-ballasted tracks over earthen structures such as embankments or retaining structures supporting high-speed trains.
12.5.1.2 Downdrag Force (DD)
Possible development of downdrag on piles or shafts shall be considered. Recommended negative skin friction values shall be as provided for the particular site in the geotechnical reports described in the Geotechnical chapter, or as a minimum refer to AASHTO LRFD BDS with California Amendments Article 3.11.8.

12.5.1.3 Earth Pressure (EV, EH)
Substructure elements shall be proportioned to withstand earth pressure. Recommended soil parameters, vertical and lateral earth pressure loads, and surcharge loads shall be as provided for the particular site in the geotechnical reports described in the Geotechnical chapter.

A. Vertical Earth Pressure (EV)
Depth of cover shall be measured from the ground surface or roadway crown, or from the street grade, whichever is higher, to the top of the underground structure. Saturated densities of soils shall be used to determine the vertical earth pressure. For recommended values, refer to the Geotechnical chapter.

B. Lateral Static Earth Pressure (EH)
For lateral static earth pressures, refer to the Geotechnical chapter.

12.5.1.4 Earth Surcharge (ES)
Surcharge loads (ES) are vertical or lateral loads resulting from loads applied at or below the adjacent ground surface. For procedures for determining surcharge loads, refer to the Geotechnical chapter.

12.5.1.5 Earth Settlement Effects (SE)
Earth settlement effects (SE) are forces or displacements imposed on a structure due to either uniform or differential settlement under sustained loading. For settlement calculation, refer to the geotechnical reports described in the Geotechnical chapter.

Structures shall be designed to accommodate earth settlement effects. Uniform and differential foundation settlements shall be subject to the allowable limits as given in the Geotechnical chapter. Refer to Section 12.8.6.18 for additional requirements.

At and near water crossings, scour potential shall also be considered for earth settlement effects.

12.5.1.6 Creep Effects (CR)
For Primary Type 1 structures, the CEB-FIP Model Code shall be used for determining effects due to creep of concrete (CR). For Primary Type 2 and secondary structures, the requirements in AASHTO LRFD BDS with California Amendments Article 5 shall be used for determining effects due to creep of concrete (CR).

Rail-structure interaction forces due to the constraint of structural movement to creep effects shall be considered as specified in Section 12.5.3.4.
12.5.1.7 Shrinkage Effects (SH)
For Primary Type 1 structures, the CEB-FIP Model Code shall be used for determining effects due to shrinkage of concrete (SH). For Primary Type 2 and secondary structures, the requirements in AASHTO LRFD BDS with California Amendments Article 5 shall be used for determining effects due to shrinkage of concrete (SH).

Rail-structure interaction forces due to the constraint of structural movement to shrinkage effects shall be considered as specified in Section 12.5.3.4.

12.5.1.8 Secondary Forces from Prestressing (PS)
Secondary forces from prestressing (PS) effects shall be accounted for in design. Such secondary forces arise during prestress of statically indeterminate structures, which produce additional internal forces and support reactions.

Rail-structure interaction forces due to the constraint of structural movement due to secondary forces from prestressing shall be considered as specified in Section 12.5.3.4.

12.5.1.9 Locked-in Construction Forces (EL)
Locked-in construction force effects (EL) resulting from the construction process shall be considered. Such effects include, but are not limited to, jacking apart adjacent cantilevers during segmental construction.

12.5.1.10 Water Loads (WA)
The effects of ground or surface water hydrostatic force, including static pressure of water, buoyancy, stream pressure, and wave loads (WA) shall be considered using the requirements in AASHTO LRFD BDS with California Amendments Article 3.7. Recommended values given in the geotechnical reports described in the Geotechnical chapter shall be used.

Adequate resistance to flotation shall be provided to resist uplift on structure foundations based upon larger of either the maximum probable height of the water table defined in the geotechnical reports described in the Geotechnical chapter, or the maximum flood condition described in the hydrology report. For the completed structure, uplift resistance shall consist of the dead load of the completed structure and applicable permanent loads.

Hydrostatic pressure shall be applied normal to surfaces in contact with groundwater with a magnitude based on the maximum probable height of water table and the applicable water density.

The change in foundation condition due to scour shall be investigated per AASHTO LRFD BDS with California Amendments Article 3.7.5.