Embankments

Design Manual
Chapter 200
Geotechnical Design
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> ***Quick Tips:***
>
> - Embankments over 10 feet in height will generally require stability and settlement review/analyses.
> - Settlement evaluations must consider the effect of time rate on the construction schedule.

Embankments are usually built by compacting earthen materials in place. The construction of embankments is covered by Section 2107 of the Standard Specifications. The compressibility and strength of the earthen embankment is a function of material, as well as the compactive effort used to place the material. Embankment performance depends on the overall stability, settlement, material properties, and construction. Embankment design should address settlement (foundation and embankment materials), slope stability, and foundation material bearing capacity. Additionally, special attention should be given to the drainage of the embankment to reduce the potential risk of embankment saturation and possible subsequent reduction in shear strength, which may result in slope instability. This section provides general guidance in the design and analysis of embankments including:

- Earth embankments that are constructed of soil materials.
- Rock fill embankments, as defined by the Iowa DOT, consisting of rock fragment material that when excavated is too large to be placed in layers of the thickness prescribed in the earth embankment section.
- Lightweight embankments containing lightweight fill or recycled materials as a significant portion of the embankment volume. Lightweight fills are most often used to reduce potential settlements and/or to reduce stability problems.

Embankment stability evaluations and settlement analyses should be performed on all critical embankment section(s) and varying soils profiles. The selection of the critical embankment section or sections is left to the geotechnical engineer of record. However, the following should be considered in the selection process:

- Height of slope, maximum height.
- Steepest slope, change in slopes.
- Soft underlying soils (alluvial soils, peat, existing fill, etc.).
- Whether critical to performance of a structure (bridge, culvert, etc.).
- Varying subsurface conditions, including sloping shale surfaces.

Site Conditions

The S1 Event (200B-1) and S2 Event (200B-2) are intended to identify and define potential and final borrows and major soil related (geotechnical) problems, and to do a preliminary design of necessary stability features that require additional right-of-way. The S2 work will also generate site characterization information (field and laboratory testing) for use in final soils related design for roadways S3 (200B-3) and structures S4 (200B-4) events.

As part of the S2 Event, borings are taken at prescribed locations along the proposed route and at potential borrow areas. Subsurface investigation general guidelines and requirements are outlined in 200C-1. The site investigation may need to include reconnaissance that encompasses the embankment plus areas outside the proposed embankment footprint. The reconnaissance might even need to extend two to three times of the width of the embankment, on both sides of the embankment, and to or beyond the top or bottom slopes adjacent to the embankment. Areas below the proposed embankment should be fully explored not only with consideration for the proposed embankment, but also if any existing landslide activity is suspected. It may be impossible to completely and accurately characterize the soil profile because of the variability between the widely spaced boring locations. Therefore, Iowa DOT field staff need to be able to recognize that soil materials have changed and make the proper field adjustments.

Embankment Materials and Compaction

Earth Embankment

Procedures for constructing earth embankments are described in Section 2107 of the Standard Specifications. Suitable and unsuitable materials for construction of embankments with earthen materials are defined in Section 2102 of the Standard Specifications.

Rock Embankment

Procedures for constructing rock embankments are described in Article 2107.03, J, of the Standard Specifications. Material is considered rock embankment when the excavated material consists of rock fragments too large to be placed in layers of the thickness prescribed in the earth embankment section. Rock fill should not be placed in areas where foundations or utilities are planned. Rock embankment construction can be applied to (used with respect to) boulders that are encountered in an earth grading operation. It can also be applied to (used with respect to) mass rock embankments that are composed mostly or entirely of good quality, stable rock materials (those not subject to degradation, such as shale and other inferior rocks) that are generated in a rock excavation. However, mass rock embankments should be discussed with all applicable and appropriate parties before they are used so that all concerns that may exist are known and properly addressed.

Lightweight Embankment

Procedures for constructing lightweight fill embankments are typically described in a project specific Special Provision. Lightweight fill materials that may be used include geofoam, cellular concrete, or lightweight aggregate. Lightweight fills are typically used for bridge abutment or MSE wall fill to reduce potential settlements.

Embankment Stability Assessment

With proper precautions and engineering judgment, embankments 10 feet or less in height with normal side slopes could feasibly be evaluated based on past precedence and engineering judgment, provided there are no known problem soil conditions such as organic soils, soft/loose alluvial or other soils, loess, or peat. Embankments over 10 feet in height or any embankment on soft soils, in unstable areas/soils, or those consisting of light weight fill require stability analyses, as do any embankments with side slope inclinations steeper than normally used. Embankments designed since about 2010 would typically have 3.5H:1V foreslopes. Prior to that date, embankments would typically have been constructed with foreslopes of 3H:1V to 2.5H:1V; however, some of the oldest constructed embankments may have foreslopes as steep as 1.5H:1V to 2H:1V. Conduct slope stability analysis according to Section 200F-1.

Stability Assessment Key Issues

Prior to the start of the stability analysis, the geotechnical designer should determine key issues that may affect the assessment such as:

- Is the site underlain by soft soils or materials such as peat? If so, a staged stability analysis or ground improvement may be required.
- Are site constraints such that slopes steeper than normally used required? If so, a slope stability assessment is needed to evaluate the various alternatives.

- Is the embankment temporary or permanent? Factors of safety for temporary embankments may be lower than for permanent ones, depending on the site conditions, adjacent features, and the potential for variability. For example, a Factor of safety of 1.2 may be acceptable for a temporary embankment under some circumstances.
- Will the new embankment impact nearby structures or bridge abutments? If so, additional sampling, testing, and analysis may be needed.

Methods of Improving Embankment Stability

In some cases, remedial treatments will be required in order to satisfy the minimum Factor of Safety (FOS) requirements. The particular method of treatment will be selected on the basis of constructability, economics, potential site restraints, and other factors. In general, an increase in slope stability safety (increase in FOS) can be achieved by implementing any or a combination of the following measures:

- Removal and replacement of the weak material.
- Construction of a stability berm.
- Construction of a toe berm/buttress or shear keys.
- Soil reinforcement with steel, geosynthetic, and/or other materials.
- Installation of subdrains or other drainage systems.
- Instrumentation and control of embankment construction (staged construction).
- Installation of a structural support such as a retaining wall.
- Construction of a granular blanket over weak foundation soils to avoid base failure.
- Base reinforcement.
- Ground improvement (multiple types may be appropriate).
- Lightweight fills:
    - Geofoam.
    - Lightweight aggregate.
    - Light weight cellular concrete.

Embankment Settlement

Settlement occurs with any new embankment construction when extra load is added to the underlying soils, which causes those soils to strain (settle). In general, a settlement analysis is likely to be necessary in areas where embankment heights are in excess of 10 feet and/or where soft soils are present. The change in stress beneath embankments is a function of embankment geometry including height, footprint, and side slope configuration. In general, settlement of embankments may be of concern in soil conditions such as soft soils (including channel fills), normally consolidated loess, or peat, depending on embankment height. However, other situations may also require analysis and need to be checked. The Soils Design Section has developed a spreadsheet (for internal use only) to calculate and evaluate settlement. This method is used by the Soils Design Section in most situations; however, other analysis procedures may be used by the Soils Design Section when appropriate and needed.

Embankment settlement consists of three components: immediate (elastic or instantaneous), primary consolidation, and secondary compression. Immediate settlement (S_i) typically occurs during construction, and should be evaluated because the amount of immediate settlement could have an effect on existing structures, shrinkage, and possibly even borrow excavation quantities. The amount of settlement resulting from primary consolidation (S_c) and secondary compression (S_s) settlement will be a function of time. The time rate of total settlement should be determined and compared to performance and construction limitations and requirements established for the project.

Settlement of the embankment and associated structures should be based on field, laboratory, and in-situ data obtained on subsurface materials below and within the embankment. When necessary, elastic theory should be used to determine immediate settlement. Consolidation testing should be used to determine primary consolidation and secondary compression settlement. Specific attention should be given to bridge and culvert structures where settlement directly below and adjacent to the culvert/bridge could affect the performance of that structure. Differential settlement along a culvert and between a culvert and wingwalls should be considered in the design. All procedures used for estimation of settlement should be referenced.

Settlement Mitigation Methods

Some of the corrective measures that could be applied to mitigate settlement or reduce construction delays resulting from long settlement time rates are:

- Undercut (remove) the compressive soil and replace with engineer approved soils.
- Wick drains or vertical sand drains, sometimes used in conjunction with preloading and/or surcharging, to accelerate settlement.
- Preloading the site with a surcharge load.
- Ground improvement such as vibrocompaction, rammed aggregate piers, stone columns, dynamic compaction, soil mixing.
- Lightweight fill to reduce the applied embankment stress.
- Subsurface drainage systems.

Settlement Monitoring

On some grading projects, monitoring of the settlement is required to determine when the embankment settlement has reached a level in which the performance criteria will be satisfied. To aid in this determination, settlement plates (see Section 2106 of the Standard Specifications and Standard Road Plan EW-212) are installed to measure the amount and rate of movement. This is done quite frequently around bridge abutments to help determine when abutment piles may be driven. These measurements, in conjunction with a measurement of the fill height, are compared to predicted values. With additional analysis, the actual time delay period can be established and/or modified (reduced or increased). If monitoring of the settlement plates is required, the settlement plate readings are to be submitted to the Soils Design Section on a weekly basis (unless no readings were taken) rather than waiting until the final review.

Chronology of Changes to Design Manual Section:

200F-002 Embankments

1/15/2014	NEW New