

Section 6

Materials

February, 2024 version



COLORADO

Department of Transportation

Office of the Chief Engineer

Table of Contents

6.01 Pavement Analysis for Distress 6-1

6.02 Preliminary Soil Survey 6-2

6.03 Geotechnical Services 6-3

6.04 Geohazard Services 6-6

6.05 Life Cycle Cost Analysis 6-8

6.06 Pavement Justification Report 6-9

6.01 Pavement Analysis for Distress

An existing pavement's condition and measured distresses are analyzed and a pavement design, either full reconstruction or rehabilitation, is developed for each individual project.

A pavement analysis is performed by the region Materials Engineer to determine the existing pavement condition and to determine the type of new pavement or rehabilitation will be required on the project.

The principal factors in choosing pavement type or treatment are subgrade and bedrock properties, traffic volume, climate, material properties and a Life Cycle Cost Analysis (LCCA).

The two types of pavements used are portland cement concrete pavement (rigid) and hot mix asphalt (flexible). A LCCA, will be prepared for all appropriate projects with more than three million dollars in material cost. The analysis will compare full reconstruction, rehabilitation, or both of rigid or flexible pavements, Alternative pavement designs and life cycle costs are discussed in "Section 6.05" of this manual.

The Resident Engineer must be in contact with the region Materials Engineer at the inception of the project to allow sufficient time to perform a detailed pavement analysis and LCCA if required. The region Materials Engineer will prepare the distress reports, pavement analysis and design, and pavement justification report. The region Materials Engineer reviews the analysis and design performed when it is prepared by a consultant.

After a proposed project involving pavements has been scoped, the region Materials Engineer performs the following:

1. Field Condition Survey and Preliminary Soil Survey Investigation.
2. Selection of Pavement Design.
3. Pavement Justification including LCCA if required.

The region shall retain a copy of the pavement justification in the project file and send a copy to the Pavement Design Unit's manager.

Additional Resources:

Colorado Department of Transportation (CDOT) Pavement Design Manual (latest edition and any applicable addendums to the Pavement Design Manual)

CDOT Roadway Design Guide

6.02 Preliminary Soil Survey

The preliminary soil survey includes drilling soil samples for one or more of the following: proposed pavement reconstruction, rehabilitation, widening, new roadway alignment, or changes in grade cut and fill areas. Additional information on the preliminary soil survey requirements for pavement design purposes can be found in Chapter 4 of the Colorado Department of Transportation (CDOT) Pavement Design Manual. If the project will consist of roadway widening, new alignments, or changes in grade cut and fill areas, it is recommended that Soils & Geotechnical Services also be consulted during project development, or scoping, or both. See Section 6.03 of this manual.

The preliminary soil survey is required to examine sites of proposed cut and fill areas in order to identify potential or existing groundwater problems, soil issues, design parameters, and support characteristics that are pertinent to the design and performance of pavements. A more detailed geotechnical investigation should be conducted to evaluate those same elements as they relate to structures such as Concrete Box Culverts (CBC's), bridges, and retaining walls, or potential geohazards (see Sections 6.03 and 6.04 of this manual).

The region Materials Engineer or the Resident Engineer usually initiates the request to the region Materials personnel for preliminary soil survey investigation and drilling soil samples for the proposed projects.

If the equipment available to region personnel is not capable of drilling to the prescribed depth of a cut area or performing the needed drilling methods or procedures, the Soils & Geotechnical Services within Materials & Geotechnical Services or a commercial drilling Contractor may be needed to provide the drilling services and sampling needed.

Region Materials and Materials & Geotechnical Services personnel perform a variety of field evaluations and laboratory tests to characterize the pavement and pavement conditions, classify and group soils, characterize subsurface conditions, and complete CDOT forms, and soil test reports with laboratory data. Region Materials will work with project personnel or consultants to ensure soil profile information obtained during the preliminary soil survey information is provided to the project design manager or Resident Engineer overseeing the design and delivery of the project as necessary.

Region Materials personnel will ensure the following actions are taken to collect and document information required for project design:

1. Research files for existing reports on proposed sites.
2. Examine sites of proposed projects and identify need for utility clearances.

3. Assign or perform drilling of proposed locations and collect samples of subsurface materials.
4. Assign or perform laboratory testing of samples.
5. Prepare reports and provide recommendations of pavement types, pavement rehabilitation, soil and base stabilization, etc.
6. Provide soil survey results to the Resident Engineer; The Resident Engineer will assure incorporation of the information into the design plans.
7. Ensure that reports and plan sheets are submitted to the appropriate agency.

The region Materials Engineer should coordinate with the Materials & Geotechnical Services soils lab manager at the inception of the project to allow sufficient time to perform the necessary soil testing (soil classification testing and R-value tests) needed for pavement analysis and design. The region Materials Engineer will review the analysis and design when it is prepared by a consultant.

The region should retain a copy of the soil profile and test results in the project file.

During the design phase of the project, if it is determined that additional data or samples are needed, they will be obtained and a supplemental report submitted.

Additional Resources:

Colorado Department of Transportation (CDOT) Pavement Design Manual (latest edition) as well as any applicable addendums

6.03 Geotechnical Services

The Soils & Geotechnical Services of the Materials & Geotechnical Services performs a variety of field and laboratory testing, data analysis, and prepares engineering geology plan sheets and geotechnical reports. They work with and alongside the Geohazards Services (Section 6.04) to support projects with all non-pavement (materials) project needs.

The Soils & Geotechnical Services supports the regions with:

1. Foundation support (bridges, culverts, walls, non-standard lighting and signal design, etc.).
2. Roadway foundation and settlement analysis for new embankment fill greater than five feet in vertical height.

3. Infrastructural distress that may include cracking or movement of existing embankments, pavement settlement, pavement heave, wall distress, as well as supporting the Geohazards Services with landslides and sinkholes.
4. Specialty geotechnical laboratory testing not performed by Colorado Department of Transportation (CDOT) labs.
5. Construction related geotechnical issues (such as caving soils, unforeseen conditions, groundwater, etc.).
6. Non-destructive geophysical studies for underground conditions such as bedrock rippability, groundwater table locations, buried utilities, abandoned culverts, etc.
7. Reviews and comments on consultant geotechnical proposals, reports, and recommendations.
8. Please reach out to the Soils & Geotechnical Services manager if there is an item not listed above and you are unsure. Project geological challenges are too numerous to provide an exhaustive list.

Requirements for geotechnical studies should be discussed with the Soils & Geotechnical Services manager, or representative, during the project development and scoping phase so staffing and schedule can be evaluated for the project.

During the kickoff phase, when it is determined that a geotechnical study is required, the CDOT Project Engineer will send a request for a geotechnical exploration to the Soils & Geotechnical Services manager and copy the Resident Engineer. The request should include a set of plans showing the proposed overall design (all structures, embankment, new roadway alignment, etc.) in plan layout and cross section, the project schedule, and the need-by date for the final geotechnical recommendations. If proposed plans are not available, the geotechnical exploration may be delayed or additional explorations (and associated costs) may be needed. Additional personnel to be included in discussions and copied on the request may include the:

- Headquarters (HQ) Bridge Unit Lead/Project Structural Engineer involving all foundation designs for bridges, walls, culverts, lighting, and signals.
- Regional Materials Engineer involving all pavement related designs.
- Regional Hydraulics Engineer involving all waterway, drainage, and culvert designs.
- Geohazards Services manager involving all rockfall, rockcut, blasting, and hazard mitigations (see Section 6.04).

Soils & Geotechnical Services is responsible for supporting the entire statewide roadway network; therefore, two to four months may be required for scheduling, completion of drilling, lab testing, and report preparation once it is determined geotechnical services are needed on the project. In many cases, it may be recommended that consultant geotechnical services are used on projects. This may allow for an accelerated project schedule and combining material testing and design (pavement) with foundation geotechnical work. The Project or Resident Engineer should contact the Soils & Geotechnical Services manager when using a consultant to allow for support in managing their geotechnical consultant by reviewing cost estimates, work hours, statement of work, proposals, reports, and other services to ensure compliance with Colorado Department of Transportation (CDOT) standards and regulations.

The project geotechnical personnel is typically responsible for:

1. Continued communication with project staff to understand the project needs and how they relate to geological challenges.
2. Examination of site for egress, schedules, and utility clearance, if needed.
3. Performance of field studies (i.e., drilling, mapping, etc.), sampling operations, and geotechnical laboratory testing.
4. Preparation and review of engineering geology plan sheet(s) and report(s) for project design staff to reference.

The project is typically responsible for:

1. Providing right of way clearance and agreements with landowners for entry, field work, and exit of personnel and equipment.
2. Providing all needed permitting required by state and local agencies, and private stakeholders.
3. Organizing communication with Environmental Services along with providing all environmental clearances and approvals for proposed geotechnical work.
4. Providing project needs, including proposed layouts and dimensions of all structures and roadways. It is understood that project goals, design details, and needs change as design progresses. Any changes should be communicated as soon as possible to allow for the most efficient use of time and resources.
5. Traffic control funding, either by private Contractors or via internal personnel (depending on availability).
6. Funded and valid project charge number for time, materials, and travel expenses.

Additional Resources:

Colorado Department of Transportation (CDOT) Geotechnical Design Manual

CDOT Bridge Design Manual

CDOT Roadway Design Guide

CDOT Field Materials Manual (latest edition)

American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications for Highway Bridges

6.04 Geohazard Services

The Geohazards Program provides expertise in the geotechnical engineering and geologic hazard (geohazard) fields. This involves data collection, interpretation, analysis, review and design work that direct the planning, design, construction and maintenance of civil engineering and environmental projects for CDOT with respect to rock excavation and geohazard mitigation or management. The engineers and scientists in this program provide geological expertise for rockfall, rockslide, debris flow, embankment distress, and landslide geological hazard mitigation, design, construction and planning. This Program develops and maintains the statewide geohazard management system for tracking known hazard sites, directing funds, identifying statewide hazard mitigation projects, and supporting non-mitigation projects that may be affected by an existing geohazard. The Program also provides emergency services for geological hazards, highway embankment, slope and subgrade failures. The Geohazards Program works collaboratively with the Soils & Geotechnical Program to help support soils and geotechnical engineering needs statewide.

It is important to recognize that geohazards are sporadic and unpredictable. They can occur at any time from almost any location along a slope. The purpose of implementing geohazard mitigation is to reduce the risk from a known hazard at a specific location.

Geohazards Services supports the regions with:

1. Identifying and assessing geologic hazards that may affect CDOT projects.
2. Design recommendations for mitigation and resilience measures to manage the effects of geohazards.
3. Rock slope excavation design guidance.

4. Response to emergency geohazard events that have impacted the transportation network.
5. Reviews and comments on consultant geohazard and rock excavation proposals, reports, and recommendations.
6. Please reach out to the Geohazards Services manager if there is an item not listed above and you are unsure of the potential hazard effects on a project. Project geological challenges are too numerous to provide an exhaustive list.

Requirements for managing geohazards on Colorado Department of Transportation (CDOT) projects should be discussed with the Geohazards Services manager, or representative, during the project development and scoping phase so staffing and schedule can be evaluated for the project.

Geohazards Services is responsible for supporting the entire statewide transportation network. In many cases, it may be recommended that consultant geohazards services are used on projects. The Project or Resident Engineer should contact the Geohazards Services manager when using a consultant to allow for support in managing their consultant by reviewing cost estimates, work hours, statement of work, proposals, reports, and other services to ensure compliance with CDOT standards and regulations and best practices. This work is often combined with geotechnical services work and performed by the same consultant.

Geohazard Services personnel or consultant representative is typically responsible for:

1. Continued communication with project staff to understand the project needs and how they relate to geological challenges.
2. Examination of site for egress, schedules, and utility clearance, if needed.
3. Performance of field studies (e.g., drilling, mapping, aerial reconnaissance etc.).
4. Preparation and review of hazard mitigation design sheet(s) and report(s) as applicable for project design staff to reference.
5. Field layout of mitigation systems

The project is typically similarly responsible for items as described in Section 6.03 Geotechnical Services.

Additional Resources:

CDOT Geotechnical Design Manual

Colorado Department of Transportation (CDOT) Bridge Design Manual

CDOT Roadway Design Guide

CDOT Procedural Directive 512.1, Project Scoping and the Design Scoping Review (DSR)

CDOT Standard Specification for Highway Bridges

6.05 Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) of alternative pavement designs is an economic analysis performed to examine two or more pavement designs for new construction, reconstruction, or pavement rehabilitation. The LCCA is prepared for all appropriate reconstruction or rehabilitation projects with material costs greater than three million dollars by comparing flexible and rigid designs and various other parameters. For new construction and reconstruction projects, the pavement structure will be designed for both flexible and rigid pavements. On resurfacing and rehabilitation projects, various methods to restore the roadway structure are considered. The Resident Engineer will provide accurate project limits, proposed typical section width, up-to-date traffic counts, and a project description with available budget. The region Materials Engineer will determine preliminary pavement type and thickness for each alternative prior to the Field Inspection Review (FIR). The Resident Engineer will develop preliminary quantities for the different pavement types. When possible, the life cycle costs for each alternative should be based on actual quantities.

Based on information provided for the LCCA, if one alternative is projected to cost more than 10 percent than the other alternative the selection is made by the region Materials Engineer. A comparison that yields results within 10 percent will require a decision by the Pavement Type Selection Committee or alternative bidding.

Refer to the Pavement Design Manual for more details on the LCCA and Pavement Type Selection Committee (PTSC) processes.

Additional Resources:

CDOT Pavement Design Manual (latest edition)

American Association of State Highway and Transportation Officials (AASHTO) Policy Guide for Geometric Design of Highways and Streets

6.06 Pavement Justification Report

The Pavement Justification Report documents the analysis and procedure the region used to arrive at the selected pavement type or rehabilitation method.

The report should include the following:

1. An analysis supporting the pavement type selection or rehabilitation method.
2. Life cycle cost analysis of alternate designs.
3. Pavement distress survey of existing pavements.
4. Pavement thickness calculations of alternate designs.
5. Final recommendations for typical sections.
6. Surfacing plan. Any additional information used to determine and justify the pavement type.

The region Materials Engineer shall approve the pavement justification report and submit the report to the appropriate Program Engineer, Resident Engineer and the Pavement Design Program manager near the date of the Field Inspection Review (FIR). The pavement justification report shall be maintained in the region's project records.

Additional Resources:

Colorado Department of Transportation (CDOT) Pavement Design Manual (latest edition)