Chapter 300
Bases - 21

This chapter is not part of the Project's specifications but is a guide for project personnel in interpreting CDOT specifications, understanding ASTM, AASHTO, and Colorado Procedures (CPs) for testing, and for completing CDOT forms.

The design and construction of a pavement structure may include one or more base courses. A base course is a layer of material below the wearing surface of a pavement. Bases may be constructed of gravels, mixtures of soil and aggregate, mixtures of asphalt and aggregate, mixtures of cement and aggregate or soil, or other innovative materials. Bases may be made of unbound materials, such as gravel, or bound materials, such as lime-treated subgrade.

Base courses under concrete pavements provide a drainage layer, reduce pumping, provide protection against frost damage, and provide support for the heavy equipment used for placing concrete pavements. There is some increase in structural capacity when a base is placed under a concrete pavement, but it is typically not a significant amount.

Base courses under flexible pavements provide a significant increase in structural capacity. The pavement design of flexible pavement depends on the wheel loads being distributed over a greater area as the depth of the pavement structure increases. There are the added benefits of improved drainage and protection against frost damage.

ITEM 206 STRUCTURE BACKFILL
ITEM 304 AGGREGATE BASE COURSE

Compaction of unbound bases is important for the stability of the pavement it supports. The maximum dry density is established in the laboratory before construction. During construction measurements of the base dry density are compared to the maximum dry density. The requirements for compaction of aggregate base course (ABC) are shown in Subsection 304.06 of the Standard Specifications for Road and Bridge Construction. Structure Backfill has similar requirements as shown in Subsection 206.03.

Two methods to determine the maximum dry density of soils are AASHTO T 99 and AASHTO T 180. AASHTO T 99 is similar to ASTM D 698 and is commonly referred to as the Proctor Test, as it was first proposed by R. R. Proctor in 1933. AASHTO T 99 uses a 5.5 lb. rammer dropped from 12 in. When a 4 in. mold is used, three layers are compacted with 25 blows on each layer. When a 6 in. mold is used, three layers are compacted with 56 blows on each layer. AASHTO T 99 results in a compactive effort of 12,400 ft-lbf/ft^3. AASHTO T 180 is similar to ASTM D 1557 and is commonly referred to as the Modified Proctor Test. AASHTO T 180 uses a 10 lb. rammer dropped from 18 in. When a 4 in. mold is used, five layers are compacted with 25 blows on each layer. When a 6 in. mold is used, five layers are compacted with 56 blows on each layer. This results in a compactive effort of 56,000 ft-lbf/ft^3. Comparing compactive efforts, AASHTO T 180 produces four and a half times the compactive effort than a sample receives compacted according to AASHTO T 99.

AASHTO T 99 is the appropriate standard for compaction of cohesive soils, particularly if there is the potential for swelling when saturated. AASHTO T 180 is appropriate for granular soils, such as aggregate base course and Structure Backfill, Class 1.

There are four methods of determining moisture-density relationships by AASHTO T 180:

- Method A uses a 4 in. mold and the fraction of the soil passing a No. 4 sieve. AASHTO states that this is applicable to soil mixtures that have 40% or less retained on a No. 4 sieve.

- Method B uses a 6 in. mold and the fraction of the soil passing a No. 4 sieve. AASHTO states that this is applicable to soil mixtures that have 40% or less retained on a No. 4 sieve.

- Method C uses a 4 in. mold and the fraction of the soil passing a 3/4 in. sieve. AASHTO states that this is applicable to soil mixtures that have 30% or less retained on a 3/4 in. sieve.

- Method D uses a 6 in. mold and the fraction of the soil passing a 3/4 in. sieve. AASHTO states that this is applicable to soil mixtures that have 30% or less retained on a 3/4 in. sieve.

The Gradation requirements for Class 1 Structure Backfill and ABC are shown in Subsections 703.08 and 703.03 respectively. A review of the Gradation requirements shows that many granular materials will meet the Gradation requirements and exceed the limits of application stated in AASHTO T 180.

Colorado has developed a rock correction formula in Colorado Procedure 23 (CP 23) when AASHTO T 180 is used:

$$MDD = (P_f \times D_f + P_c \times 0.95\ D_c) / 100$$

The standard practice within the Department follows:

- 110 lbs. of granular material are sampled and sent to the laboratory before construction begins. This would typically require two standard sample bags.
- The material is separated into two fractions, material retained on a No. 4 sieve and material passing a No. 4 sieve.
- The specific gravity and absorption of the material retained on a No. 4 sieve is determined according to AASHTO T 85 Specific Gravity and Absorption of Coarse Aggregate.
- The maximum dry density and optimum moisture of the material passing a No. 4 sieve is determined according to AASHTO T 180, Method A.
- For bases with crushed concrete or reclaimed asphalt pavement (RAP), an accurate specific gravity determination is difficult to make. For these materials T 180, Method D is used.
- Method D may be used if more than 30% of the material is retained on the No. 4 sieve, but has 30% or less of the material retained on the 3/4 inch sieve. When Method D is used, use the above procedure but substitute the 3/4 inch sieve for the No. 4 sieve.

During construction, the control of compaction follows according to the plans, specifications, and the Frequency Guide Schedule for Minimum Materials Sampling, Testing, and Inspection. Each field test must include a separation of the sample into the two fractions, material retained on a No. 4 sieve, and material passing a No. 4 sieve. Percent relative compaction is determined according to CP 25. CP 23 is used to correct the maximum dry density and optimum moisture for soil-rock mixtures with more than 5% material retained on a No. 4 sieve.

ITEM 308 PORTLAND CEMENT & FLY ASH

Sources of Portland cement and/or fly ash are listed on the Department's Approved Product List. To verify a specific cementitious material that may be considered for a project check if the supplier/manufacturer of the cement or fly ash is on the Approved Products List at the web site address of: https://www.codot.gov/business/apl

If a manufacturer wants to add a cement or fly ash source use the same website and follow the instructions within Notice to Manufacturers: https://www.codot.gov/business/apl/manufacturers.html and also follow all references within CP 11:

CDOT Materials Forms - Applicable for Bases

https://www.codot.gov/library/forms/form-numbers-broken-down

Materials Forms, Instructions & Examples Chapter

NOTE: The example forms are still in development, as they are completed they will be entered into the chapter. Use the relevant example forms from the The electronic version of the 2018 FMM.

Form	Title
157	Field Report for Sample Identification or Materials Documentation
6	Field Tests of Base Aggregate, Fillers, Paving and Miscellaneous Aggregates
38	Aggregate Test Report - [*computer output*] SiteManager
194	Structure Backfill Density Report
564	Soils and Aggregate Sieve Analysis When Splitting On the No. 4 Sieve
565	Sieve Analysis For Aggregate Not Split On the No. 4 Sieve
633	Sample Tag (Sacks)
1126	Stabilometer Record of Item 304 Aggregate Base Course
1296	Granular Materials Moisture – Density Report - [*computer output*] SiteManager

FS# = (Contract ID-Seq.#)

COLORADO DEPARTMENT OF TRANSPORTATION

FIELD REPORT FOR SAMPLE IDENTIFICATION OR MATERIALS DOCUMENTATION

Region		_ _ _ _ _ – _ _ _ _
Contract ID		Date Submitted
Project No.		
Project Location		

Material Type			Field Lab phone		Cell Phone
Material Code (LIMS)	Item	Class	Grading	Special Provisions ☐ yes	
Previously used on Project No.:		Previous CDOT Form #157 F/S No.(s):		☐ CDOT Form #633 (sack) ☐ CDOT Form #634 (can)	

- Sample Identification: Quantity & Unit of material submitted, describe tests required, precise location sample remove from (Stationing). etc.
- Materials Documentation: Field inspected (describe appearance, weight/dimensions, model/serial number), COC &/or CTR provided etc.

Central Lab use only:

Sample ID (#1)	Sample ID (#2)	Sample ID (#3)
Sample ID (#4)	Sample ID (#5)	Sample ID (#6)

APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:
APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:

Preliminary ☐	Construction ☐	Maintenance ☐	Emergency ☐	Date needed

Contractor	Supplier
Sampled from (Pit, roadway, windrow, stock, etc.)	Pit name or owner

Quantity represented	Previous quantity	Total quantity to date

Sample submitted: ☐ Yes ☐ No	Shipped specified quantity to: ___ ☐ Central lab ___ ☐ Region lab ___ ☐ Consultant lab	Date

Sampled or inspected by (print name)	Title	E-mail
Supervisor (Pro./Res./Matls. Engr./Maint. Supt.) (print name)	Title	Residency

Distribution: Chemical Lab: cdot_chemlab@state.co.us
Concrete Lab: cdot_conc.lab@state.co.us
Flexible Pavement: cdot_flex.lab@state.co.us
Physical Properties: cdot_phpr.lab@state.co.us
Soils Lab: cdot_soils.lab@state.co.us
Region Labs: Send completed form with sample

Previous editions are obsolete and may not be used. CDOT Form #157 04/18

Project File: SMM – Upload completed form into the attachment icon on the sample record

FS# = (Contract ID-Seq.#)

COLORADO DEPARTMENT OF TRANSPORTATION
FIELD TESTS OF BASE AGGREGATES, FILLERS, PAVING AND MISCELLANEOUS AGGREGATES

Contract ID	Region	
Project No.		Date Submitted
Project Location		Item

SMM/LIMS Sample ID (or Test # [Date])	Station	Tons (t) or Yards (y)	Field density	Lab max density	% Rel. Comp.	Total moist.					#4	#8	#30	#50	#100	#200	L.L.	P.I.
Sheet Total			Specifications:															
Previous Total																		
Total to Date														Final report:			yes ☐	no ☐

Spec. deviations: yes ☐ ☐

Items:
206 Structure Backfill Class 1 ________
206 Filter Material Class________
304 ABC Class________
307 Treated Subgrade________
403 HMA Grading________
403 SMA________
409 Cover Coat________
Other Material:

P=____________% for lot # ____________

Remarks

Source (pit)	
Project Tester (print name)	Title
PE Approved by (print name)	Title

Distribution: SMM/LIMS: Form is not required to be completed
Non-LIMS: Completed form in project material book

Previous editions are obsolete and may not be used

CDOT Form #8 11/17

COLORADO DEPARTMENT OF TRANSPORTATION **STRUCTURE BACKFILL DENSITY REPORT**	Region	Date Submitted
	Contract ID	
	Project No.	
	Project Location	

Major Structures

Number of Structures: (1 test/200 cu. yds.; minimum 1/structure)	Class 1 (cu. yds.)	No. of tests	Class 2 (cu. yds.)	No. of tests
Total cu. yds. structure backfill:				

Cross Drains

Number of Cross Drains: (1 test/200 cu. yds.; minimum 1/structure)	Class 1 (cu. yds.)	No. of tests	Class 2 (cu. yds.)	No. of tests
Total cu. yds. structure backfill:				

Side Drains

Number of Side Drains: (1 test/200 cu. yds.; minimum 1/structure)	Class 1 (cu. yds.)	No. of tests	Class 2 (cu. yds.}	No. of tests
Total cu. yds. structure backfill:				

Other

	Class 1 (cu. yds.)	No. of tests	Class 2 (cu. yds.}	No. of tests

Remarks		
Print name	Signed	Title

Resident Engineer

Previous editions are obsolele and may not be used. CDOT Form 194 04/2020

COLORADO DEPARTMENT OF TRANSPORTATION

SOILS AND AGGREGATES SIEVE ANALYSIS WHEN SPLITTING ON THE No. 4 SIEVE

Contract ID	
Project No.	
Item	Class

Pit name	Station	Test no.	Sample weight	Date

Sieve	Wet wt.	Dry wt.	Individual percentage		Percent passing	Specs
+ #4						
- #4				#		
Total				#		
				#200		

Sample ID	

	Moisture correction
Liquid limit	Plus #4 moisture sample
Plastic limit	Wet weight
Plastic index	Dry weight
Soil class.	Loss
"R" value	% moisture
Sampled by	Minus #4 moisture sample
Tested by	Wet weight
	Dry weight
	Loss
	% moisture

Minus #4 wash

	Sieve	Weight (grams)	Individual percentage		Percent passing
Wet weight (grams)	#				
	#				
Dry weight (grams)	#200				
	- #200				
	Total				

NOTE: Save all material until calculations are completed in case a check is necessary

Pit name	Station	Test no.	Sample weight	Date

Sieve	Wet wt.	Dry wt.	Individual percentage		Percent passing	Specs
+ #4						
- #4				#		
Total				#		
				#200		

Sample ID	

	Moisture correction
Liquid limit	Plus #4 moisture sample
Plastic limit	Wet weight
Plastic index	Dry weight
Soil class.	Loss
"R" value	% moisture
Sampled by	Minus #4 moisture sample
Tested by	Wet weight
	Dry weight
	Loss
	% moisture

Minus #4 wash

	Sieve	Weight (grams)	Individual percentage		Percent passing
Wet weight (grams)	#				
	#				
Dry weight (grams)	#200				
	- #200				
	Total				

Previous editions are obsolete and may not be used. Page 1 of 2 CDOT Form #564 4/2020

Colorado Department of Transportation

Sieve Analysis for Aggregates CP31

Atterberg Limits T89 and T90

Contract ID:		Region:	
Project Number:			
Project Location:			
Material Description:		Pit:	
Prime Contractor:		Item:	Do not use this form for Item 203 - Soils or Item 206 - Structure Backfill Class 2, use Form 564 Split over the #4 - CP 21
Sample ID SMM:	Lab Ref Number SMM:	Class:	Test No: / Test Date:

Gradation Specimen Dry Weight (SDW):			Washed Dry Weight (WDW):	
Sieve	**Weight**	**Percent Retained**	**Percent Passing**	**Specs**
6"				
4"				
3"				
2½"				
2"				
1½"				
1"				
¾"				
½"				
⅜"				
$^{5}/_{16}$"				
¼"				
#4				
#8				
#16				
#30				
#50				
#100				
#200				
- #200		(WDW - TSW) ÷ WDW x 100 = % Diff (Spec: ≤ 0.3%)		
Total Sieved WT (TSW):		(_______ - _______) ÷ _______ x100 = _______ %		

Sample Information

Sampled From:	
Supplier Ticket No:	
Time Sampled:	
Station:	
Lane:	
Quantity Sample Represents:	
Sampling witnessed by:	
Sample Tested By:	

Sample % Moisture and Dry Weight

Pan ID:		
Pan Weight (g):		A
Pan & Sample - Wet Weight (g):		B
Pan & Sample - Dry Weight (g):		C
Sample - Wet Weight (g):		D=(B-A)
Sample - Dry Weight (g):		E=(C-A)
Moisture Loss (g):		F=(D-E)
Moisture Content (MC) %:		G=(F/E) x 100
Specimen Dry Weight:		E

If gradation sample and moisture sample are the same sample, use the dry weight (SDW) in the sieve analysis calculations.

Gradation Remarks:

Wet Weight ÷ (100 + MC %) x 100 = Specimen Dry Weight

Wet WT.____________ ÷ (100 + ________) x 100 = ____________ SDW

If a split moisture sample is used to determine dry mass of gradation sample, use calculation to determine dry weight.

Place IA Stamp Here:

Atterberg Limits:	Liquid Limit T89	Plastic Limit T90
Tin ID:		
Mass of Tin:		
Mass of Tin + Wet Soil:		
Mass of Tin + Dry Soil:		
Moisture Content %:		
Number of Blows:		

Plasticity Index		Specifications
Liquid Limit %:		
Plastic Limit %:		
Plasticity Index:		

LL % = Moisture Content @ number of blows X multiplier

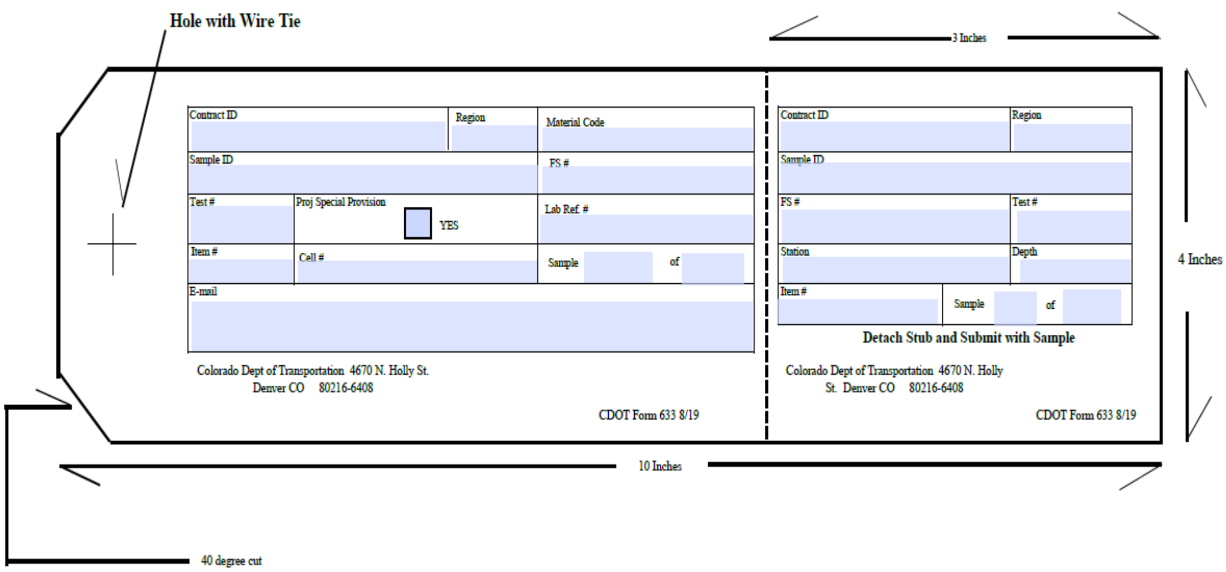
Number of Blows	Multiplier
22	0.9850
23	0.9900
24	0.9950
25	1.0000
26	1.0050
27	1.0090
28	1.0140

IA Sample ID:

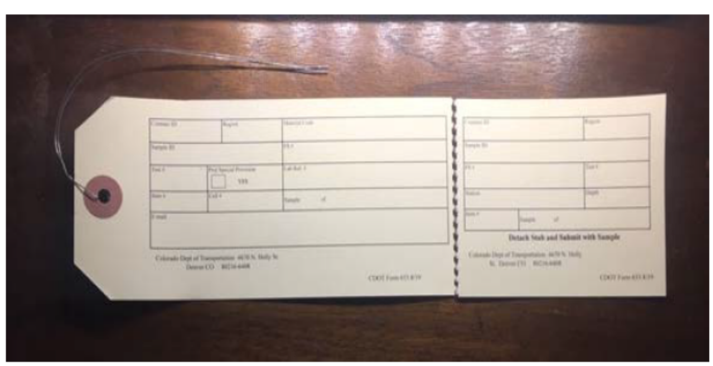
Electronic Signature of IA Personnel

Sample Remarks:

Previous editions are obsolete and may not be used. CDOT Form #565 5/18



CDOT Form 633 Tag (w/preforated tag and wire tie)



COLORADO DEPARTMENT OF TRANSPORTATION

STABILOMETER RECORD OF ITEM 304 ABC

Contract ID		Region
Project No.		
Proj. location		

Pit name	Date	Sample ID			Lab #
Represents	LL	PL	PI	SE	Class

GRADATION

Seive size	As run: % passing	As run: Scalp	Set up
4"			
3"			
2½"			
2"			
1½"			
1"			
3/4"			
1/2"			
3/8"			
#4			
#8			
#16			
#50			
#100			
#200			

Stabilometer "R" value:

% moisture at lbs. per cu. ft.

% Moisture - #4 Material		X
Weight of - #4 Material		=
Weight of H_2O		+
Initial H_2O added		=
Total initial H_2O		(A)

COMPACTION

Cylinder #				
H_2O added (B)				
Exudation pressure, lbs				
Exudation pressure, PSI				
Ht. of briquette (H)				
Wt. cylinder & wet sample				
Cylinder tare				
Wet wt. of sample (W_w)				
1 Weight of H_2O (C)				
2 Dry wt. (D)				
3 % Moisture (M)				
4 Density				
Height correction by wt.				

Set up weights

-3/4" + 1/2"	
-1/2" + 3/8"	
-3/8" + #4	
- #4	

STABILOMETER

Total load	PSI				
1000	80				
2000	160				
Displacement turns					
"R" value					
Drainage					
Exp. pressure dial reading					

1 (A) + (B) = (C)
2 (Ww) - (C) = (D)
3 (C) ÷ (D) = (M)
4 $\frac{(W_w) \times 30.3}{(100 + M) \times H}$

Previous editions are not obsolete and may not be used. CDOT Form #1126 4/14