



# Open Graded Friction Course

## Design Guidance

February 2020

California Department of Transportation  
HQ Division of Design

<https://dot.ca.gov/programs/design/hydraulics-stormwater/treatment-bmp-design-guidance>

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## Section 1

# Introduction

The purpose of this guidance is to help district designers use Open Graded Friction Course (OGFC) as a Stormwater Treatment Best Management Practice (TBMP). This guidance gives background on its current use, appropriate siting criteria, and maintenance developed by Caltrans Division of Maintenance, Office of Pavements Engineering. The referenced guides include what type of asphalt concrete to specify in coordination with Maintenance and Pavements. This guide includes: example plans, item number, specifications, costs, how to balance competing goals, draft text for environmental document, and the methodology for documenting NPDES permit compliance in SWDR.

## Section 2

# Background

OGFC has been used as an effective paving material for various reasons, including the reduction of noise and to reduce tire spray from rainfall on the highway surface for better visibility during rain events. OGFC is also referred to as Open Graded Asphalt Concrete (OGAC) in some studies (Caltrans Maintenance Technical Advisory Guide, 2003), or Caltrans item Hot Mix Asphalt Open grade (HMA-O). Further studies from other DOTs, have shown significant reduction in pollutants from OGFC pavements, compared to traditional highway pavements (dense graded asphalt concrete or Portland cement concrete surfaces (ASCE 2012) and (Caltrans 2011)). The pollutant load reduction from OGFC lanes in comparison to traditional pavement runoff characterization for pollutants, would suggest that that they are as effective at pollutant removal as many of the treatment BMPs in the Caltrans approved list. The means of pollutant removal is by particle capture in the voids of the surface of the OGFC. Caltrans already uses OGFC for noise and spray reduction, so using for the added benefit of water quality improvement is a sustainable way to provide pollutant removal and treatment of storm water runoff.

## Section 3

# Limitations

When considering OGFC as a SW treatment there should be caution in using other materials, such as rubberized OGFC (RHMA-O or RHMA-G), as the current Caltrans specification was not effective at treating stormwater, due to lower permeability rated and less water filtering through the layer and not reducing the spray on vehicles undercarriages as much. If crumb rubber is added to the OGFC layer, the water quality benefits no longer exist, due to the different gradation and specification, and therefore reducing the permeability and void space that provides the treatment. “The Project found no water quality benefit at any of the California sites where the overlay contained recycled rubber. This may be the result of insufficient permeability resulting from the use of larger amounts of rubberized binder” (Caltrans 2012). The Caltrans specification's higher percentage of crumb rubber from Texas DOT, likely causes the reduced permeability and effectiveness. For this reason, rubberized Hot Mix Open Graded Asphalt (RHMA-O) is not recommended for use as a Stormwater treatment.

Caltrans has commitments to use recycled tires in asphalt concrete by CA legislation, AB 338, and CA public resource 42703. This requirement is for statewide use of recycle rubber and not a per project basis. Caltrans also has requirements for complying with NPDES permit post construction treatment and many TMDL Waste Load Allocations. These two environmental commitments are competing in nature, due to rubberized AC (RHMA-O) not working as a treatment BMP, so each district must balance these competing goals based on their current targets for compliance. A sustainable method to comply with both goals is to place rubberized dense graded Hot Mix Asphalt (HMA) pavement or Rubberized Hot Mix Asphalt-Gap Grade (RHMA-G) and then place OGFC (HMA-O) as the surface layer meeting both Caltrans goals on one project. This may not work on every project, but is a viable option in many location that will help with statewide goals for compliance. Refer to Section 631.3 of Flexible Pavement in in the Highway Design Manual for details on layering.

## Section 4

# Siting Criteria

Appropriate locations for OGFC (HMA-O) as a treatment BMP include the following:

1. Lower elevation highways where traction sand is not applied, and freezing temperatures are rare, usually below 3,000 ft elevation.
2. Highway traveled way sections that do not receive runoff from cut sections, diked cut sections at super elevation with gutter drainage are ok. Avoid areas with sheet flow across lanes from sediment areas.
3. Highway traveled way sections that do not receive offsite sediment laden storm water flows.
4. Drainage areas that are entirely made up of impervious surfaces.
5. Any paved area except as described in the Caltrans Open Graded Friction Course Usage Guide, February 2006.
6. When crumb rubber is not added to the OGFC layer.
7. When Infiltration BMPs are not feasible.
8. Highway with greater than 50 MPH speed limits. The higher speeds help to keep the voids open for permeability. Lower speed highways may claim credits for OGFC as a treatment BMP if they provide general maintenance. General maintenance: "Water hoses, high pressure cleaners, and specialized cleaning vehicles may be used for this purpose." (Caltrans Maintenance Technical Advisory Guide - MTAG 10-15).

**Design Criteria:** The project engineer must consult with the OGFC Usage Guidance and the district pavement office to determine if OGFC is appropriate for the location under consideration. Discussion with the Traffic Operations may also be needed to consider safety factors such as ponding, icing, or unraveling. Concurrence of the pavements office should be documented in the SWDR. If the location is appropriate, then an open graded mix may be included in the plans and specification package and credit may be taken for storm water treatment. This could be used for post construction, redevelopment, alternative compliance, and potentially TMDL compliance. More detailed siting criteria can be found in the OGFC Usage Guide and other maintenance manuals referenced on the Caltrans internal intranet Office of Asphalt Pavements site.

## Section 5

# Maintenance

Maintenance interval: Same as OGFC used for other purposes, see Caltrans OGFC Usage Guidance, February 2006, page section 4.0 Maintenance. Maintenance of OGFC overlays includes removal and replacement of the failed or aged OGFC section. Maintenance division does not recommend any other treatment methods currently. For the special case of highways under 50 MPH, claiming OGFC as a treatment BMP, follow the MTAG 2008 criteria for some areas with permeability issues. Additional maintenance guidance can be found in the Caltrans Maintenance Manual Volume 1, Chapter A on flexible pavements, which includes OGFC. Maintenance activities on roadways surfaced with OGFC should avoid obstructing the lateral flow of water through the OGFC. These activities may include crack sealing or patching a small failed area with DGAG, thus creating a dam where water may be retained or stored and contribute to further failure of the OGFC surfacing. When large areas of patching are involved, OGFC should be replaced with OGFC (OGFC Usage Guide, Section 4.0).

## Section 6

# Treatment BMP Selection

OGFC is a flow through treatment device as it does not infiltrate water, though some water is captured in the OGFC voids. The NPDES Permit requires infiltration as the treatment mechanism of first priority. For this reason, designers should first use the Caltrans PPDG T-1 checklist for the appropriate BMP consideration. If these BMPs are not feasible, OGFC can provide treatment from the highway runoff and meet the NPDES permit requirements for maximum extent practicable, as an approved treatment BMP. For OGFC use on a highway, it is recommended that the entire traveled way and the shoulder be paved (HDM 630). Paving the shoulder and roadway increases the treatment area.



## Section 7

# Treatment Calculation

The treatment area is the surface area of the OGFC.

- 1 acre of OGFC = 1 acre of treatment of Caltrans Highway Storm Water

Or another way to describe is treatment is:

- Post Construction Treatment Area = New Impervious Surface- OGFC
- 1 acre of OGFC = 1 acre of pavement treated

OGFC pollutant removal treatment mechanism is filtration through the void space of the PFC layer and reduction of water splashing on the vehicle undercarriage. Treatment removal is equal to or superior to many flow through devices such as, bio-retention. A portion of the calculated treatment can be attributed to the reduction of water splashed up from the pavement and to the under body of vehicles in sections of OGFC.

## Section 8

# Pollutant Removal Efficiency

Constituent pollutant removal efficiencies from typical OGFC application for Texas and North Carolina highways was sampled and studied. The monitoring results are presented below. “Monitoring before and after the replacement showed that mean Total Suspended Solids (TSS) levels dropped from 46 mg/L to 8.7 mg/L, an 81% difference. Concentrations of total metals also decreased: lead (Pb) by 78%, cadmium (Cd) by 69%, zinc (Zn) by 66%, and copper (Cu) by 35%. Some dissolved metals (Zn and Cd) declined by about 60%. (ASCE 2012)”. Caltrans water quality monitoring showed similar results and demonstrated that the Caltrans OGFC section 39 specification for California highways was an effective BMP (CT 2012).

## Section 9

# Specifications

In general, OGFC will follow the 2022 Standard Specification and section 39-2.04 Open Graded Friction Course. OGFC designs will include asphalt binders and materials gradation, these should follow the Highway Design Manual, Caltrans Open Graded Friction siting criteria guidance, or Maintenance Technical Advisory Guide (MTAG), based on the project siting information. Additionally, these should be coordinated with the district pavement engineer for recommendations on the appropriate applications for the highway section. The water quality studies from Caltrans and other DOTs showed that OGFC layers of 1-2 inches are appropriate thickness for effective treatment BMP applications.

Comparison of material specifications shows the gradations and materials for Caltrans OGFC are similar to the Texas DOT materials, so the water quality studies can be correlated to Caltrans projects (ASCE 2012)(Caltrans 2012).

Standard Specification 2022, Section 39-2.04 OGFCs includes The Hot Mix Asphalt Open Graded (Open Graded Friction Course) item number: 390401, also referred to as HMA-O.



## Section 10

# Costs

Pavement costs vary with location and quantity. Check the latest bid prices for OGFC for your projects using the District 8 cost data base for closest project location. Follow the OGFC usage guidance and coordinate with your local pavements engineer for appropriate gradations and binders. 2021-2023 costs averaged-\$507.0 /ton, but will vary by quantity and location in the State.

**Table 10-1. Costs**

<b>Item No.</b>	<b>Item Description</b>	<b>Unit Pay</b>	<b>2015 Section</b>
390401	Hot Mix Asphalt- Open Graded (Open Graded Friction Course)	TON	39

## Section 11

# OGFC Example Design Information

### 11.1 Example Water Quality Assessment

Text for environmental document (PEAR, PID, and/or Project Report)

Caltrans projects are required to comply with the federal Clean Water Act section 402, Porter-Cologne, Water Quality Control Act, Water Code Division 7 and Related Sections (As amended, including Statutes 2018). These are incorporated in the Caltrans NPDES permit and SWMP requirements. Appendix IV of the NPDES permit includes requirements for complying with statewide Total Maximum Daily Loads (TMDLs).. Caltrans is also required to comply with CA AB 383 and the California Public Resources Code 42703, which has goals for use of crumb rubber in Caltrans pavement. Caltrans project delivery memo's, design information bulletins, and guidance recognize the importance of complying with both competing requirements and allows flexibility in how the department complies per project, with the overall statewide goal for both as the target metric for compliance.

Example per project: Caltrans is required to comply with NPDES permit Appendix IV to achieve TMDL and post construction treatment, using approved stormwater treatment BMPs to the maximum extent practicable. The public resource code and Caltrans project delivery memos allow environmental requirement justification to not use crumb rubber in all asphalt applications for highway rehabilitation and maintenance. Compliance with the Caltrans NPDES permit, CWA, and CA Porter-Cologne (Water Quality Control Act), are valid justification to not use crumb rubber RHMA-O on a project, so the OGFC (HMA-O) can function as a treatment BMP (Caltrans HDM 630).

Caltrans must meet both competing target goals, so the district pavements/maintenance engineer and the district NPDES staff were consulted and this project was approved for OGFC use, and the district is on track to meet both the recycled rubber and NPDES goals. The district pavements engineer and NPDES coordinator will continue to track the target goals and decide when each is warranted.

### 11.2 Example SWDR Text

The use of OGFC as treatment must be coordinated with a variety of Caltrans offices, to assure all of requirements are met. Project engineers may use this example text to help streamline documentation of the design coordination and decisions.

Example SWDR text: Modify for your projects unique design parameters.

This project considered infiltration treatment BMPs in accordance with the NPDES permit post construction requirements and it was determined they were infeasible due to the lack of right of way sufficient to infiltrate the water quality volume (edit per site conditions). The project location met the siting criteria based on the Caltrans, Open Graded Friction Course Usage Guidance, February 2006. The project engineer coordinated with the district pavements/maintenance engineer and determined the district is forecast to meet the recycled crumb rubber goals.

Therefore, use of OGFC as treatment BMP is appropriate and will meet the post construction requirements. The project is located in a sediment TMDL watershed, where Caltrans is listed as a stakeholder. Use of OGFC will allow the district to meet waste load allocations in addition to the post construction treatment.

### 11.3 Calculations

Measure all the surface area of the OGFC using micro station from surfaces areas (layout sheets or typical lengths and cross sections as appropriate). Then multiply by the depth for the volumetric quantity of HMA-O. Multiply the density by the volume and convert for the tonnage of HMA-O for quantity sheet in TON of material, which follows the item code above and standard specifications 39-2.04.

Density of HMA-O typical = 150 lb/ft<sup>3</sup>

Typical HMA-O layer is 0.1 ft or 1.2"

Area(ft<sup>2</sup>) x Depth (ft) x Density (lb/ft<sup>3</sup>) x 1 TON/2,000.0 lb = TON

As shown above, the area treated in acres is the direct measurement of the surface areas of the OGFC. The HMA-O pavement surface area should be shown as a separate column with (N) designation for information only, shown as acres of treatment area, so they can be used by NPDES for tracking compliance unit or treat area compliance. This information is required for tracking the Stormwater Data report and for transfer to maintenance for tracking TBMP for NPDES compliance.

## Section 12

# References

- Barret et al, Stormwater Quality Benefits of a Porous Friction Course and Its Effect on Pollutant Removal by Roadside Shoulders, Water Environment Research, Volume 78, 2006 Water Environment Federation
- California Department of Transportation, Design Information Bulletin 79-04, Design Guidance for Roadway Rehabilitation projects 2R and 3R.  
<https://dot.ca.gov/programs/design/design-information-bulletins-dibs>
- California Department of Transportation, Design Information Bulletin 81-02, CAPM.  
<https://dot.ca.gov/programs/design/design-information-bulletins-dibs>
- California Department of Transportation, Design Memo, 2023, Stormwater Project Planning and Design Guideline in Design.  
<https://dot.ca.gov/programs/design/manual-project-planning-design-guide>
- California Department of Transportation, Design Memo, 2015, Crumb rubber in HMA.  
[https://maintenance.onramp.dot.ca.gov/downloads/maintenance/files/pave\\_program/docs/Memo-wAtch\\_PDMaintOps\\_Mtce\\_CrumbRubberInHMA\\_02-10-15.pdf](https://maintenance.onramp.dot.ca.gov/downloads/maintenance/files/pave_program/docs/Memo-wAtch_PDMaintOps_Mtce_CrumbRubberInHMA_02-10-15.pdf)
- California Department of Transportation, Open Graded and/or Gap Graded Asphalt Pavements Water Quality Project End of Study Report Document No. CTSW-RT-12-290.01.1D, April 2012
- California Department of Transportation, Open Graded Friction Course Usage Guidance, February 2006 – intranet only.  
[https://maintenance.onramp.dot.ca.gov/downloads/maintenance/files/asphalt\\_paves/Recycling%20Branch/FrictionCourseGuide.pdf](https://maintenance.onramp.dot.ca.gov/downloads/maintenance/files/asphalt_paves/Recycling%20Branch/FrictionCourseGuide.pdf)
- Caltrans Highway Design Manual, Chapter 630 Flexible Pavement, -5-20-2022.  
<https://dot.ca.gov/programs/design/manual-highway-design-manual-hdm>
- Caltrans Maintenance Manual Volume 1, Chapter A, July 2014.  
<http://www.dot.ca.gov/hq/maint/manual/maintman.htm>
- Caltrans Maintenance Technical Advisory Guide, Chapter 10, 2008.  
<https://rosap.nrl.bts.gov/view/dot/27612>
- Eck B., Winston R., Hunt W., Barrett M., Water Quality of Drainage from Permeable Friction Course, Journal of Environmental Engineering, February 2012, ASCE

## Appendix A: Example of OGFC

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**Photo Example of OGFC**

*Water draining through OGFC layer to the shoulder.*

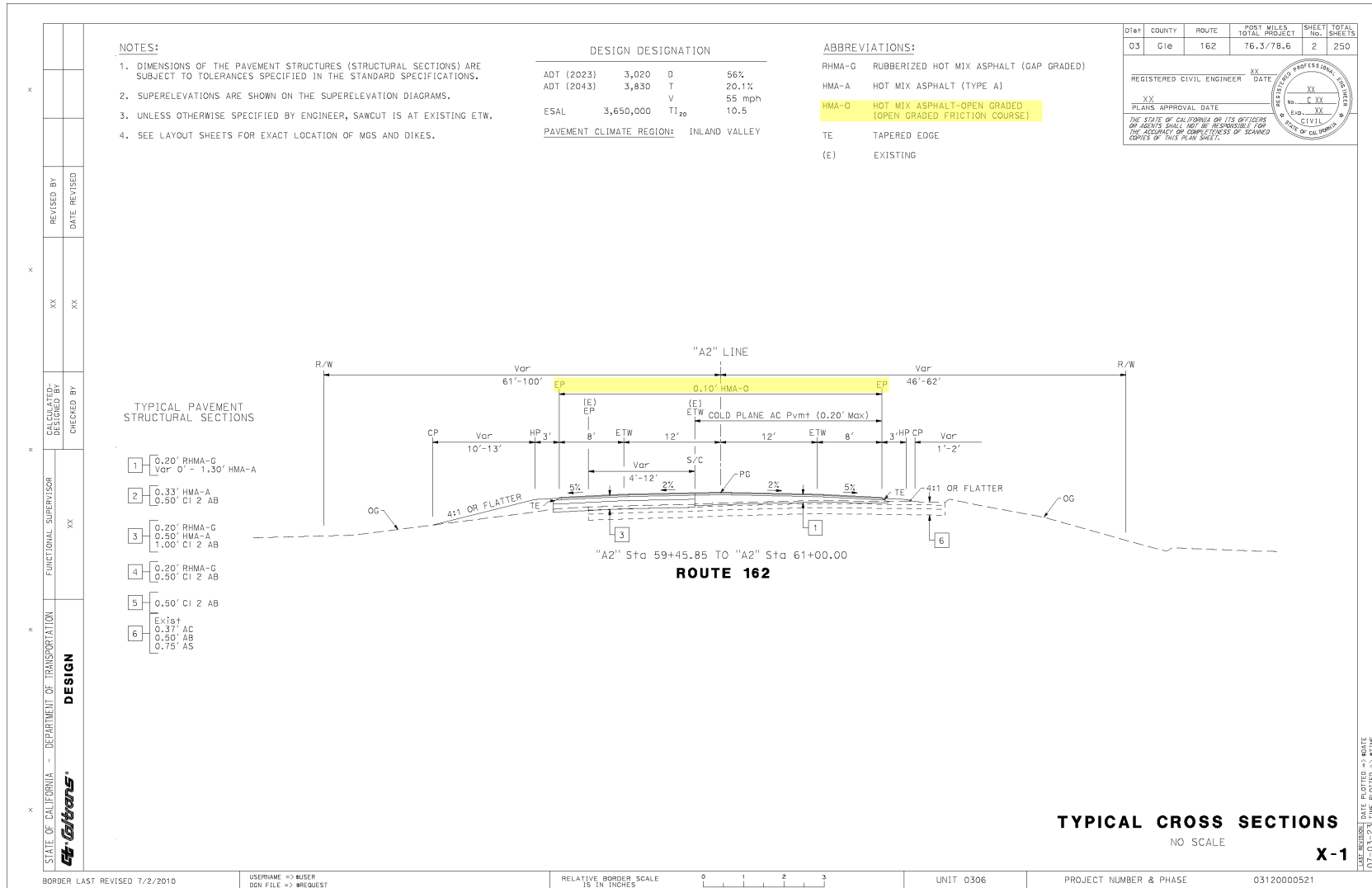
## Appendix B: Example Plan Sheets

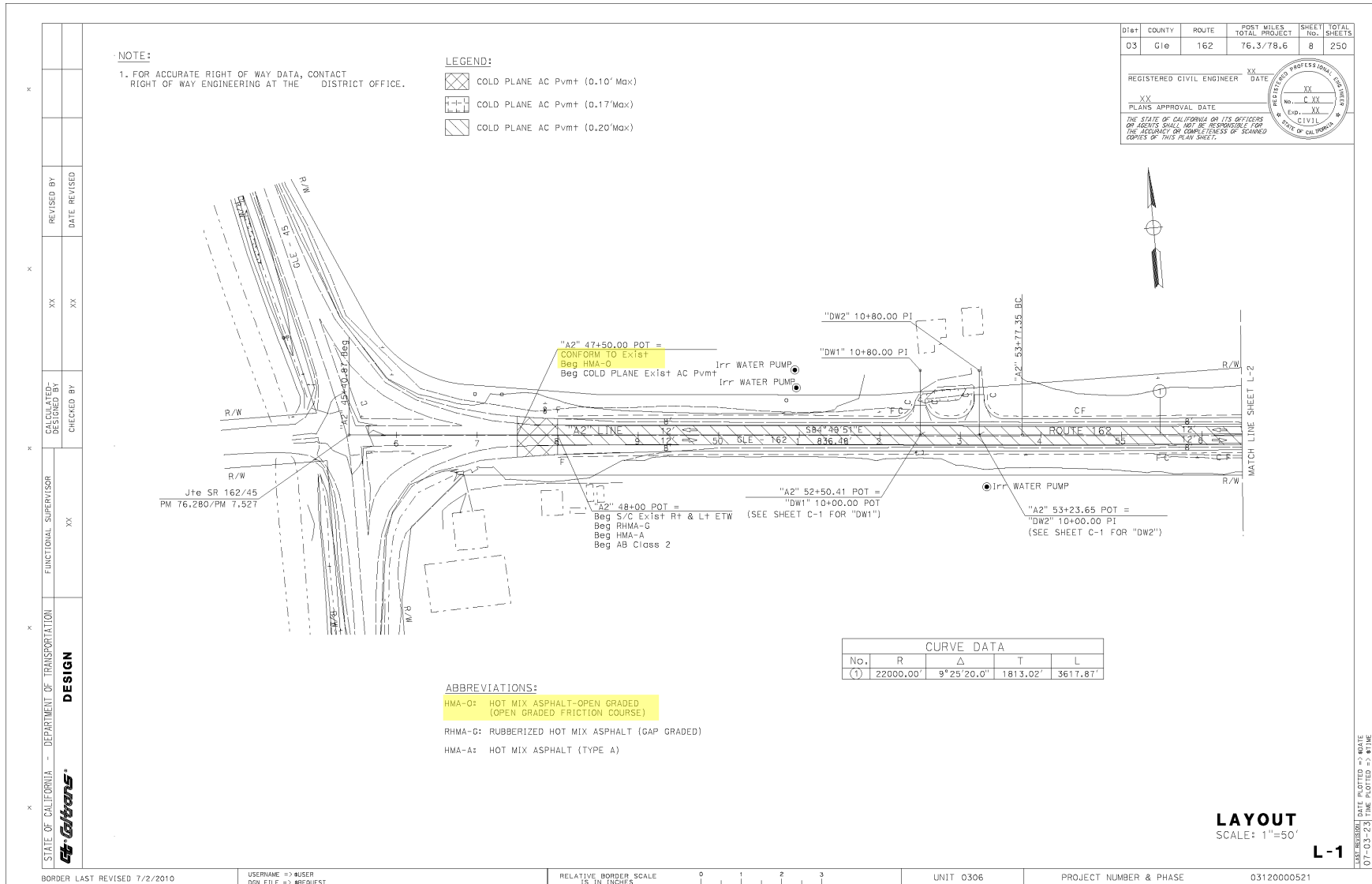
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Example Plan Sheets (Typical Cross section, Layout, and Summary of Quantity)  
Sheets X-1, L-1, and Q-1



# Open Graded Friction Course





DI&T	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
03	Gie	162	76.3/78.6	109	250

REGISTERED CIVIL ENGINEER	XX	DATE	XX
XX	XX	C. XX	XX
PLANS APPROVAL DATE	XX	XX	XX

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

**PAVEMENT STRUCTURE QUANTITIES SUMMARY**

STAGE No.	STATION	HOT MIX ASPHALT, OPEN GRADED (OPEN GRADED FRICTION COURSE) TON	RUBBERIZED HOT MIX ASPHALT (GAP GRADED) TON	HOT MIX ASPHALT (TYPE A) TON	CLASS 2 AGGREGATE BASE CY	TACK COAT TON
1	"D" 10+00 TO 14+96			124	122	
1	"A2" 48+00 L+ TO 62+50 L+ "A2" 62+50 TO 65+73 "A2" 112+59 TO 117+50 "A2" 117+50 R+ TO 153+76 R+		1485	3896	3771	6.9
1	"CR61" 10+20 TO 55+75.02		231	539	472	1.9
1	"AR1" 10+08 TO 13+25				51	
1	"AR3" 10+08 TO 12+02				32	
1	"AR8" 10+08 TO 11+80.81				43	
2	"A2" 48+00 R+ TO 62+50 R+ "A2" 117+50 L+ TO 153+76 L+		649	1672	1645	3.1
2	"A2" 48+00 TO 61+00 "A2" 123+00 TO 153+76		1557	442		5.4
2	"L1" 10+20 TO 15+33		6	14	102	
2	"L3" 10+20 TO 19+19		237	140	362	0.4
2	"A2" 47+50 TO 62+50 "A2" 117+50 TO 153+76	1933				8.4
2	"CR61" 10+20 TO 15+36	144				1.3
2	"L3" 10+20 TO 19+19	135				0.6
	TAPERED EDGE		21	202	228	
	PLACE HOT MIX ASPHALT DIKE			58.3		
	OVERSIDE DRAIN			1.2		
	<b>TOTAL</b>	<b>2212</b>	<b>4186</b>	<b>7088.5</b>	<b>6828</b>	<b>26.0</b>

**COLD PLANE AC PAVEMENT**

STAGE No.	STATION	Max		
		0-10' SOYD	0-17' SOYD	0-20' SOYD
1	"CR61" 15+36 TO 18+00	469		
1	"CR61" 18+00 TO 27+35		1662	
2	"A2" 47+50 TO 48+00	262		
2	"A2" 48+00 TO 61+05			3479
2	"A2" 123+00 TO 153+76			8101
2	"A2" 153+76 TO 154+26	136		
	<b>TOTAL</b>	<b>632</b>	<b>1662</b>	<b>11580</b>

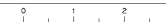
**SUMMARY OF QUANTITIES**

**Q-1**

BORDER LAST REVISED 7/2/2010

USERNAME => #USER  
DGN FILE => #REQUEST

RELATIVE BORDER SCALE  
IS IN INCHES



UNIT 0306

PROJECT NUMBER & PHASE

03120000521

DATE PLOTTED => DATE  
TIME PLOTTED => TIME

