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16. ABSTRACT
Portland cement concrete pavements (PCCP) constructed in California are of the plain jointed design. These PCC pavements generally develop faulting, or step-off, at the transverse joints. However, the magnitude and rate of this faulting varies considerably throughout the state. Faulting, through the pumping process, has been a major factor in slab cracking and subsequent poor pavement performance.

Previous Caltrans research revealed that the mechanism of pavement faulting is caused by the pumping process. One of the major contributors is surface infiltrated water that has become trapped in the relatively impermeable structural elements.

This study presents an evaluation of the effectiveness of edge drains as a method of providing rapid drainage of surface-infiltrated water and thereby delaying or preventing pumping and subsequent faulting.

Over a three year period, research indicates that edge drains are very effective in reducing faulting of PCC pavement in California.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF FACILITIES CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

EVALUATION OF EDGE DRAIN PERFORMANCE

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic years (yd^3)	3.785 .02832 .7646	litre (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) (1000 lbs) kips	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (in-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi$\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ (MPa$\sqrt{m}$)
	pounds per square inch square root inch (psi$\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ (KPa$\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

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The author wishes to thank Jim Erickson and Bill Smith of Caltrans District 2 in Redding, and the materials section personnel of Caltrans District 3 in Marysville, for their input and field investigations that contributed significantly to the evolution of the present edge drain design. Also I wish to thank Henry Jerzak who helped me collect the faulting measurements at the monitoring sites.

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INTRODUCTION

The major portion of portland cement concrete pavements (PCCP) constructed in California are of the plain jointed design. All of these PCCP generally develop faulting (step-off) to some degree at the transverse joints whether they are in cut or fill and whether they are on the high side or low side of the superelevation. The magnitude and rate of this faulting varies considerably throughout the state.

Research and experience indicate that this faulting of PCCP in California is a major factor leading to cracking and eventual slab breakup. Extensive research (1,2) has been conducted on the subject of PCCP faulting. For the phenomena to occur, the following conditions must exist:

1. Environmental factors that create differential thermal and moisture gradients thru the slab, resulting in drying shrinkage of the concrete that causes upward curling or warping of slab edges and subsequent deflection under loading,

2. A source of water. Surface water infiltration thru cracks and joints (especially the pavement/shoulder joint) in the PCCP. Because most structural section materials are relatively impermeable, this water remains trapped within the structural elements for long periods of time,

3. Heavy wheel loads crossing the curled slab transverse joints. The sequential vertical movement of abutting slab ends under traffic loading tends to cause movement of fine particles and water from beneath the down-stream slab and adjacent untreated aggregate base located beneath the shoulder. This transfer is further facilitated by the springing rebound of the slab from which the wheel has just departed, thus creating a suction coincident with the expulsion of water and fines from under the downstream slab being depressed by the load.

4. Pumpable fines must be present. It has been found for California PCCP that sources of fine material available for pumping action and migration, in order of significance are:

a. Adjacent shoulder aggregate base material.

b. Loose surface fines of stabilized bases (CTB) underlying PCCP.

c. Foreign material entering through pavement joint system.

As a result of the action described under (3) above, any loose fine material available is driven in the direction opposite to traffic flow and is deposited under the upstream side of the joint (Figure 1). In many cases, the depth of buildup of these fines has been found to coincide with measured faulting or step-off of the joint.

This faulting phenomena causes eventual uneven slab support which causes slab cracking. Over time, further cracking by the same process leads to total slab breakup. Rapid removal of surface infiltrated water should reduce the time period during which the pumping process is active, thereby delaying pavement faulting and eventual slab breakup (Figure 2).

The objectives of this research were threefold:

1. Determine the effectiveness of edge drains in reducing pavement faulting.

2. Optimize design features that have been incorporated in previous edge drain systems that Caltrans District 2 maintenance forces experimented with as far back as 1974.

3. Investigate methods to clean and/or restore inoperative edgedrain systems.

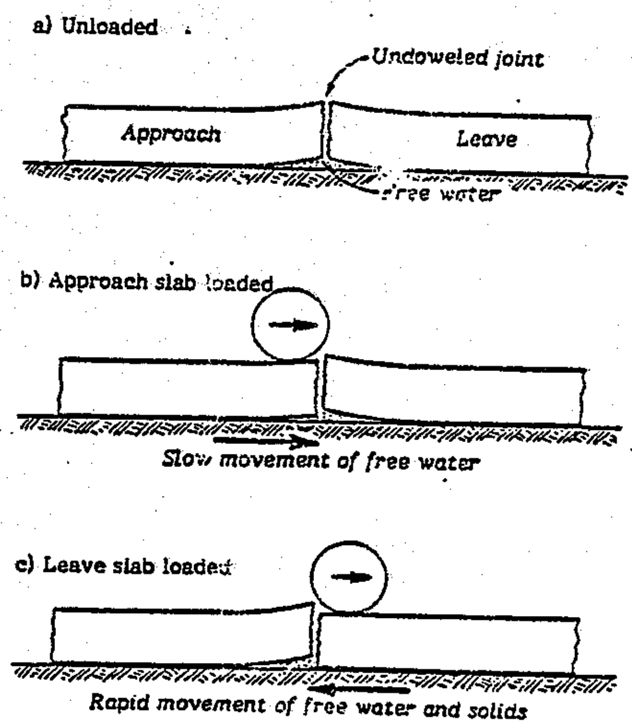

Figure 1

Faulting Process

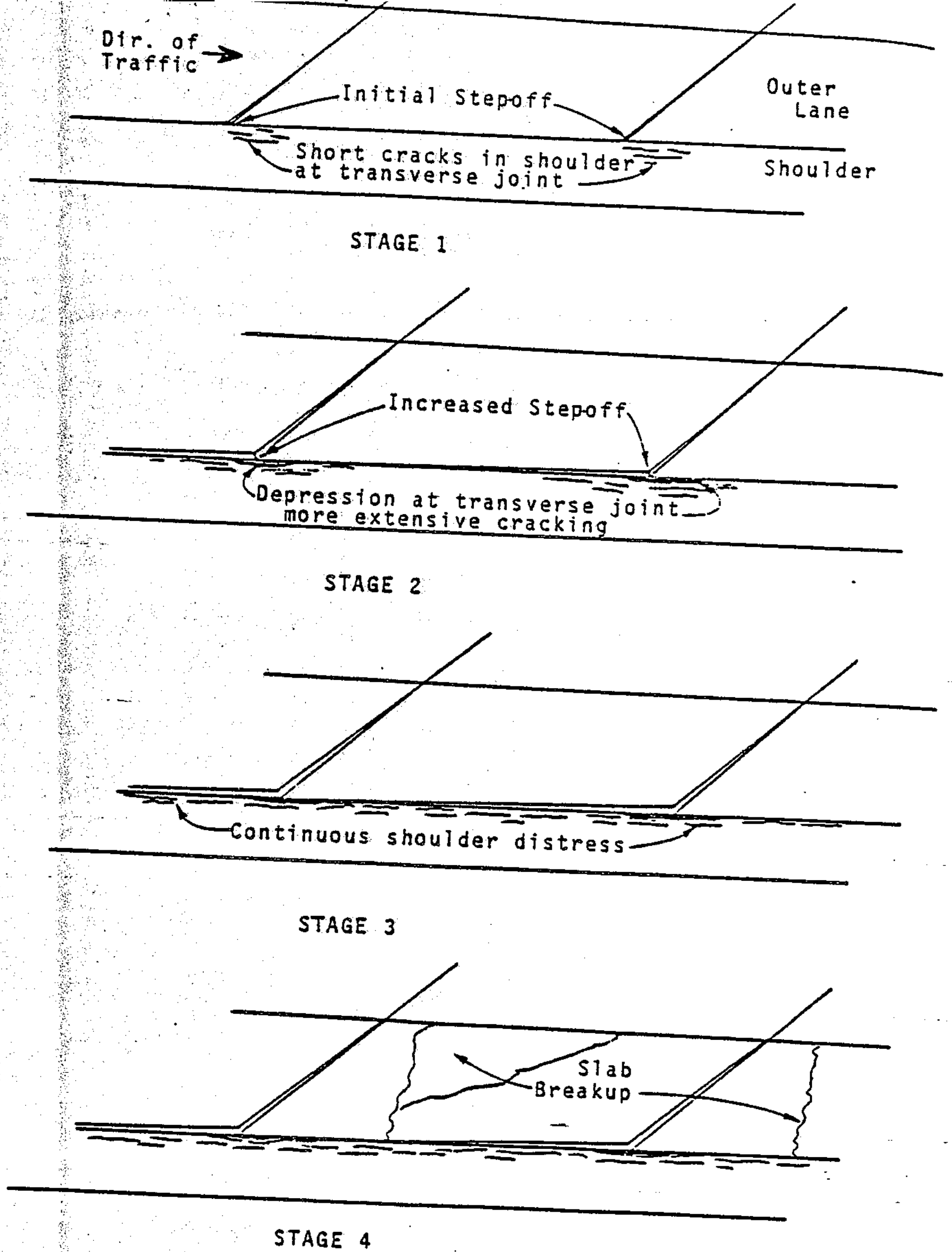

Figure 2

TYPICAL STAGES IN THE LIFE OF A CONCRETE PAVEMENT

This report presents research results that indicate that edge drains provide rapid removal of surface infiltrated water, thereby reducing the faulting rate by draining these portland cement concrete pavements. It also contains documentation of design, construction and maintenance problems that were resolved during this study. Standard specifications, special provisions and standard plans for edge drains are also included (for information) in the Appendices of this report.

METHODOLOGY TO EVALUATE EDGE DRAIN PERFORMANCE

Previous PCCP performance research(1,2) has tried several methods to quantitatively measure step-off or faulting. In the planning stages of this research project, it was thought that the Portland Cement Association (PCA) type road meter, similar to that used for determining ride scores for the Caltrans Pavement Management System (PMS) surveys, could be used to measure pavement faulting. However, it was determined that good repeatability of the "counts-per-mile" measurements could not be obtained. Identifying the variables involved when using the ride meter was considered to be beyond the scope of this project, so use of the road meter was rejected in favor of direct measurement of faulting. A simple frame with a dial gauge reading to the nearest 0.001 inch was used to measure the faulting of individual pavement slabs. The device was placed so that the gauge would measure the faulting one foot in from the shoulder at each pavement joint and read to the nearest 0.01 inch (Photo 1).

Twenty-five consecutive joints were measured at each test site. The recorded measurements were arithmetically averaged to obtain an average fault measurement for the twenty-five consecutive joints.

During each visit to each site, visual surveys were also made to record the number and location of slab cracks and evidence of pumping (stains) on the shoulder or pavement. The performance of the edge drain during storms and any outlet erosion were also noted.

By graphing "fault measurements" vs "time" for each edge drain and control monitoring site and then using a least squares linear regression, the faulting rate in "inches per year" was determined. By comparing the faulting rates of the edge drain sites and the control sites, the effectiveness of the edge drain systems was then determined.

DESCRIPTION OF MONITORING SITES

The edge drain installations studied were either retrofit (edge drain installed some time after original construction) or new construction (edge drain installed during the original contract). The design of some of the earlier edge drains varied from the current design. In most cases, untreated pea gravel was the permeable material placed around the edge drain, and some installations did not use a filter fabric against the shoulder side of the trench to prevent migration of the shoulder aggregate base fines. For the design details of the two current types of installation, refer to the Revised Standard Plan titled "Subgrade Drain Details," RSP-D98-D, in Appendix 4.

Edge drain installations to be surveyed were installed between 1975 and 1982. Wherever possible, the monitoring sites included a control with no edge drain adjacent to the site with the edge drain. Every attempt was made to have similar longitudinal grades, traffic, and the same original contract for both the control and the edge drain sites.

Monitoring sites were established at permanent post mile markers for ease of reference and resurvey.

The first monitoring sites were established where retrofit and new construction edge drains were already in service. As other projects became available, monitoring sites were established at these locations. An effort was also made to establish sites in a variety of geographic areas. The sites were subsequently grouped together to represent three geographic areas. These areas are listed below in order of increasing average annual rainfall.

1. San Joaquin Valley
2. Sacramento Valley
3. Russian River Valley

RETROFIT EDGE DRAIN FEATURES

Twenty-nine sites (17 edge drain and 12 control sites) were monitored. These sites represent a variety of environmental and traffic conditions. Unfortunately, two edge drains and two control sites were overlayed with asphalt concrete before the study was completed so data from these locations are not included in the results of this study.

Twelve of the edge drain sections contained untreated permeable material (UTPM) and five edge drain sections were constructed using cement treated permeable material (CTPM) for the drainage medium. At the time of this study, an asphalt treated permeable material (ATPM) drainage medium, which is now one of Caltrans' standards, was not available. PVC edge drain pipe diameters were either 1 1/2 or 2-inch.

Retrofit drains were constructed using one of three lateral outlet designs:

1. A continuous longitudinal slotted edge drain with a tee every 200 to 300 feet connected to a solid pipe outlet (T system).

2. A 200 to 300 foot slotted edge drain with an elbow at the low end connected to a solid pipe outlet (L system).

3. A 200-300 foot slotted edge drain with a 30 inch sweep ell at each end connected to solid pipe outlets for venting, drainage and cleaning (U system).

NEW CONSTRUCTION EDGE DRAIN FEATURES

Six monitoring sites (three edge drain and three control sites) were established. These drains were installed on portions of going contracts by contract change order. The plans called for PCCP over lean concrete base (LCB). The edge drains were the T system, using a continuous slotted PVC edge drain pipe with a Tee connected to solid pipe outlet every 200 to 300 feet for discharging the water.

One edge drain design used no permeable material around the longitudinal pipe. The edge drain was placed on the LCB against the side of the PCC slab. Backfill consisted of aggregate base that was isolated from the drain by filter cloth tacked with asphalt emulsion to the slab face and to the top of the LCB.

The other edge drain design used untreated permeable material with filter cloth to retard the intrusion of shoulder fines.

EVALUATION OF EFFECTIVENESS OF EDGE DRAINS

It was planned to evaluate each site at least three times a year. However, due to manpower constraints, weather, and other higher priority work, this was not always accomplished. Each evaluation consisted of obtaining fault measurements, noting slab cracking and adverse outlet erosion and, during rainy periods, observing if the the drains were functioning.

In general, the drains would commence flowing 15 to 30 minutes after the start of a steady rain. Major flow would cease approximately 1 to 2 hours after the rain stopped; however, some outlets would drip for several days afterward, particularly where longitudinal grades were relatively flat.

Faulting measurements vs time were graphed for each monitoring site. A least squares linear regression was performed to determine the slope or rate in "inches per year" of faulting. A (+) rate indicated that the faulting rate was increasing with time and a (-) rate indicated that the faulting rate was decreasing with time.

An examination of the graphs indicated that several factors influenced the magnitude of the faulting measured and its change with time. These factors were:

1. The age and initial faulting of the pavement. The rate of faulting is not constant throughout the life of a pavement.

2. Inherent curl of PCC slabs. This is influenced by temperature and moisture gradients within the slab and subgrade.

3. The condition of the CTB.

4. An inability to place the gauge in exactly the same spot each time without using lane closures. Because of the costs and hazards associated with establishing lane closures, this procedure was considered to be appropriate.

An examination of the data for retrofit and new construction edge drains and for the control sections revealed a linear trend, but with considerable scatter of the data points. However, while in a statistical sense there may be poor correlation, the trends are distinct considering the short time of evaluation period.

1. Retrofit Edge Drains

The following table summarizes the retrofit monitoring sites data. It contains the location (district, county, route, post mile and direction of travel), purpose (control or edge drain), type of permeable material used (untreated or cement treated), linear regression faulting rate in inches per year, the number of slab cracks existing at the site when the study started and the number of cracks at the site when the study finished, and the length of time in months during which monitoring was accomplished. It should be noted that some of the monitoring sites have a long period of monitoring. These sites were incorporated from previous research(1,2).

TABLE 1 Summary of Retrofit Edge Drain and Control Sites

(1) Dist.	(2) Co.	(3) Rte.	(4) PM	(5) Direction	(6) Site	(7) Permeable Material	(8) Faulting Rate	(9) Total Slab Cracks Start	(10) Finish	(11) Time
2	Teh	5	23.05	NB	C	-	0.017	1	1	25
2	Teh	5	23.45	NB	D	UTPM	-0.010	6	6	46
2	Teh	5	25.65	NB	D	UTPM	-0.008	1	1	46
2	Sha	5	14.0	NB	D	UTPM	0.003	13	14	46
2	Sis	5	11.17	NB	C	-	0.012	13	13	116
2	Sis	5	11.17	NB	D	UTPM	0.003	13	13	29
3	Yol	5	9.98	NB	C	-	-0.009	0	0	27
3	Yol	5	9.98	NB	D	CTPM	-0.006	5	5	27
3	Col	5	18.72	NB	C	-	-0.003	3	3	46
3	Col	5	21.0	NB	D	UTPM	0.004	0	2	46
3	Col	5	21.48	SB	C	-	0.004	13	19	46
3	Col	5	21.48	SB	D	UTPM	0.0008	9	12	46
3	Gle	5	0.75	NB	C	-	0.009	0	0	46
3	Gle	5	0.75	NB	D	UTPM	0.005	0	0	46
3	Gle	5	7.15	SB	C	-	0.001	0	3	46
3	Gle	5	4.0	SB	D	UTPM	0.007	1	1	46
4	Son	101	45.02	NB	C	-	0.017	0	2	64
4	Son	101	45.02	NB	D	CTPM	-0.007	2	2	45
4	Son	101	44.90	NB	D	UTPM	-0.001	0	1	52
4	Son	101	45.50	NB	D	CTPM	0.002	5	5	34
4	Son	101	46.54	SB	C	-	0.0003	6	6	22
4	Son	101	46.54	SB	D	CTPM	-0.014	1	1	22
5	SB	101	69.0	SB	C	-	0.007	19	19	106
5	SB	101	71.4	SB	D	Sand	0.009	22	22	106
10	SJ	205	4.0	EB	C	-	0.012	0	0	104
10	SJ	205	4.0	EB	D	UTPM	0.003	0	0	57
10	SJ	205	11.0	WB	D	UTPM	-0.006	5	6	42
10	SJ	580	9.0	EB	C	-	0.009	0	0	23
10	SJ	580	9.0	EB	D	CTPM	0.010	0	2	23

Legend:

(1) District (2) County (3) Route (4) Post Mile
(5) Direction NB=northbound, SB=southbound, etc.
(6) C = Control, no edge drain
D = edge drain
(7) UTPM = untreated permeable material
CTPM = cement treated permeable material
(8) Faulting rate (inches per year).
(9) Total number of slab cracks (start of study).
(10) Total number of slab cracks (end of study).
(11) Monitoring period in months.

Average faulting rate of all the control sites = 0.006 inch/year
Average faulting rate of all the edge drain sites = -0.0003 inch/year

Comparisons of faulting rates within original job limits did not appear to be particularly significant. However, when all the faulting rates were averaged for the control and edge drain sections, a significant difference was found. To further refine the data, three distinct geographic areas were examined. These were the San Joaquin Valley, the Sacramento Valley, and the Russian River Valley. The results are summarized in Table 2.

TABLE 2 Faulting Rates by Geographic Area

Valley	County	Average Annual Rainfall inch/year	Average Control Faulting Rate inch/year	Average Edge Drain Faulting Rate inch/year
San Joaquin	San Joaquin	10-20	0.015	0.0003
Sacramento	Yolo Colusa Glenn Tehama	20-30	0.002	0.0003
Russian River	Sonoma	40+	0.009	-0.004

An examination of the average faulting rates in Table 1 and 2 clearly indicates that edge drains have reduced the faulting rates of PCCP with retrofit edge drains. An analysis was made to determine if there was a relationship between average annual rainfall and faulting rate, and/or the volume of truck traffic and the faulting rate, for both the control and edge drain sites. The analysis indicated there was no relationship between rainfall or truck traffic and the faulting rate. However, previous faulting research(2) suggested that higher faulting rates were generally associated with areas of higher rainfall. Since the previously cited study provided longer term performance, rainfall was established as a criteria for prioritizing retrofit edge drains (see Appendix 6).

Due to the difference in pavement age, prior traffic service, future traffic service, and the initial faulting of the retrofit drain sites, there was considerable concern regarding the effect on in-service faulted PCCP when positive drainage was subsequently provided. These concerns were:

1. That partial removal of previously pumped fines from beneath the slabs could create uneven slab support and cause broken slabs under traffic loading.

2. That the the drainage system might plug up very rapidly.

Analysis of the data indicated that additional slab cracking within the edge drain section was no more severe than that in the control sections during the study period. Item "2" is discussed in "Optimizing Design Features and Restoring Drainage Capacity."

Surveys taken during fault monitoring measurements and observations during storms indicated that all control (non-edge drain) sections showed signs of pumping stains on the shoulder (Photo 2). Only two edge drain monitoring sites exhibited pumping (stains) on the shoulder during rain. However, this pumping ceased shortly after the rain stopped. All other edge drain monitoring sections exhibited no evidence of pumping (stains) on the shoulders (Photo 3).

The asphalt concrete backfill of the longitudinal trench of all retrofit edge drain installations containing untreated permeable material was depressed, particularly at the transverse joints (Photo 4). These depressions ranged from slight to so severe that extensive patching or complete repair was required by maintenance forces. Investigation indicated that these untreated cohesionless backfill materials were sometimes difficult to compact and had a tendency to settle with time. Also, the pumping process readily moved the untreated permeable material to a position beneath the slabs, thereby contributing to the faulting. Observation of edge drain sites using cement treated permeable materials indicated little to no depression of the longitudinal trench.

The Caltrans District 3 Materials Section investigated several UTPM edge drain installations. It was evident from test holes through the edge drain trench and pipe that, in some cases, considerable amounts of fine material were plugging the permeable material and the edge drain (Photo 5).

Prior to this investigation, during the Caltrans Lab "Model Slab Faulting Study"(2), an edge drain wrapped in filter cloth was used to study the effect of drainage on the faulting process. It was clearly demonstrated that filter cloth wrapped around the longitudinal drain pipe can become completely plugged with fine material and render the edge drain inoperative. These results dramatically indicated what could be expected in a field installation using a filter cloth encapsulated edge drain system. Fines would eventually clog the filter cloth and not allow the surface infiltrated water access to the edge drain. Thus, the faulting process would then resume.

Results of outlet erosion surveys indicated that erosion of fine grain soils can be severe if outlets are not designed properly. Splash pads, as shown on the Standard Plan Detail, worked well when flush with the ground so water doesn't run off and down the lip and cause erosion (Photo 6). This type is also satisfactory from a maintenance view point, in that it does not present a hazard to maintenance activities and is not easily damaged by equipment.

2. New Construction Edge Drains

These drains were installed on portions of going construction projects in Caltrans District 10. While they are not of the present edge drain design, it was important to evaluate their effectiveness in conjunction with LCB.

All edge drains in this section used filter cloth to prevent aggregate base shoulder fines from migrating under the pavement slabs.

Table 3, below, summarizes the data collected from these sites.

TABLE 3 Summary of New Construction Monitoring Sites

(1) Dist.	(2) Co.	(3) Rte.	(4) PM	(5) Direction	(6) Site	(7) Permeable Material	(8) Faulting Rate	(9) Total Slab Cracks Start	(10) Total Slab Cracks Finish	(11) Time
10	SJ	5	36.0	NB	C	-	-0.006	3	4	57
10	SJ	5	34.0	NB	D	None	0.0004	3	3	57
10	SJ	5	44.0	NB	C	-	-0.002	1	1	42
10	SJ	5	42.0	NB	D	UTPM	0.002	2	7	42
10	SJ	5	41.0	SB	C	-	0.003	0	0	42
10	SJ	5	44.0	SB	D	UTPM	-0.001	0	0	42

Legend:

(1) District (2) County (3) Route (4) Post Mile
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CTPM = cement treated permeable material
(8) Faulting rate (inches per year).
(9) Total number of slab cracks (start of study).
(10) Total number of slab cracks (end of study).
(11) Monitoring period in months.

The average faulting rate of the control sites was -0.002 inch per year.

The average faulting rate of the edge drain sites was 0.0005 inch per year.

These are probably not significant rates as these pavements were constructed in 1977 and 1979 on LCB. The initial and final fault readings were so small that they were more likely a measurement of pavement curl as opposed to actual faulting or step-off of the pavement joints.

Increased slab cracking was most significant on the edge drain section at PM 42.0, NB. The reason for this is not clear as filter cloth was used to prevent migration of unstabilized aggregate base fines from the shoulder and LCB was used. One possible explanation is reflective cracking of LCB up through the PCCP.

Pumping stains were again noted at all the control (non-edge drain) sites (Photo 7), but no stains were present on the shoulders of the sites containing edge drains (Photo 8).

OPTIMIZING DESIGN FEATURES

Observation of the construction and performance of the edge drains described herein has resulted in several changes in the edge drain design used by Caltrans. Following are the general features of the current design:

1. Previous studies(2) have indicated that the slab/base interface is where the pumping process is occurring. Thus, this is the most efficient and effective location to intercept and quickly remove infiltrating surface water.

2. Two-inch PVC pipe slotted at the third points appears to satisfy most edge drain needs (Appendix 1). This provides more capacity than the 1 1/2-inch pipe and, no matter how the pipe is laid in the trench, some slots will be near the bottom of the trench and thereby prevent ponding in the permeable material near the slab/base interface.

3. Filter cloth (Appendix 3) should be placed along the shoulder side and bottom of the trench to prevent migration of aggregate base fines into the drainage medium. Complete encapsulation of the drainage element with filter cloth, however, can cause fines to accumulate along the pavement side of the fabric and eventually eliminate the ability of the drain to provide an outlet for surface water infiltrating the structural section. More importantly, there is no technique at this time to effectively remove this filter cake and restore drainage.

4. The use of CTPM or ATPM (Appendices 1 and 2) has been made mandatory to provide a porous, rigid, nonerodible material adjacent to the slab (Photo 3). The use of untreated permeable materials has resulted in surface settlement of longitudinal edge drain trenches. This is due in part to difficulties in compacting cohesionless aggregate in a narrow trench and also to the removal of some of the fine permeable material by the pumping process (photo 4).

5. Lateral pipes should be solid PVC pipes without slots. Four of the monitoring sites used slotted pipes as outlet drains. These and similar installations required extensive maintenance repairs because of erosion along the length of the outlet pipes. This is further aggravated by roots growing thru the slots, plugging the pipes, and thereby forcing water out of the slots (Photo 9).

The use of 30 inch sweep ell connections at the ends of the edge drain every 200 to 300 feet to connect the outlets makes maintenance cleaning of the system considerably easier (Appendices 4 and 5).

Where long edge runs are necessary, intermediate clean-outs are required. This was the subject of a value engineering study. The main purpose of the study was to determine if there was a cheaper clean-out assembly design than that presently being used. This study resulted in the implementation of a more economical clean-out assembly detail in early 1985 (Appendix 5).

6. Soil conditions at the edge drain outlets should be considered for potential erosion at the design stage and the appropriate outlet detail should be chosen from the standard plan.

Formed-in-place cement treated drainage channels should not be used at edge drain outlets because cracks form in the cement treated material from shrinkage and soil movements due to seasonal wet/dry cycles. It is more cost-effective to pipe water to a ditch rather than use cement treated channels.

Because debris from the slot cutting has plugged some of the outlet screens and because there is no evidence that rodents will nest in the 2-inch-diameter pipe, it has been recommended that the outlet screens be removed from the standard plan detail (photos 10 and 11).

RESTORING DRAINAGE CAPACITY

The retrofit edge drain installed on 3-Col-5 near Williams, California, in 1979, exhibited severe plugging of the edge drain during an investigation of the drainage system (Photo 5). A minor maintenance contract was awarded to place clean-out valves so that the "L" system, using elbows, could be flushed (Photo 12). Some difficulty was encountered in operating the high pressure hose and nozzle since only one end of the pipe was accessible. However, a large amount of fines was removed from the system. The next rain indicated that the flushing had restored the system's drainage capability (compare Photo 13 and Photo 14). Obviously, periodic flushing of the system must be accomplished to obtain continuous effective drainage of the structural section.

CONCLUSIONS

The findings of this research have to be viewed as trends because of the short time period comprising the study. A true picture of edge drain performance can only be determined after several years of careful monitoring. However, after short-term monitoring of some of the oldest edge drain installations, the following conclusions appear warranted at this time.

1. Edge drains are effective in removing surface infiltrated water and reducing the rate of pavement faulting.

2. Treated permeable materials will preclude depression of the AC shoulder trench backfill, particularly on retrofit edge drains. Also, no deterioration of the shoulder next to the PCCP will occur if treated permeable materials are used on new construction.

3. Treating the permeable material by adding cement or asphalt will eliminate a potential source of fines that could otherwise contribute to further pavement faulting.

4. Periodic flushing of edge drains appears to restore drainage capacity and is vital to future pavement performance.

5. Edge drains do not appear to have a short-term effect on slab cracking in either retrofit or new construction systems.

6. The most cost-effective strategy for retrofit edge drains is to install them on the most recently completed projects. A "priority rating" was developed in 1982 for the Office of Highway Maintenance (Appendix 6).

RECOMMENDATIONS AND IMPLEMENTATION

As this study progressed, some negative field performance was observed. Among these were the settlement of the untreated backfill in the longitudinal trench, the untreated backfill becoming part of the pumping process, a need to isolate the shoulder aggregate base fines, the use of slotted pipe outfalls for lateral drainage, and the inability to flush the system containing 90° elbows. As these problems were identified, the use of cement or asphalt treated permeable material (Appendices 1 and 2) to preclude settlement and additional pumping, the use of filter fabric (Appendix 3) placed on the shoulder side of the trench to isolate shoulder fines, the use of solid pipes for lateral drainage to prevent erosion, and the use of 30-inch sweep ells to facilitate cleaning were incorporated into the Standard Special Provisions and the Standard Plan details for edge drains (Appendix 4).

In summary, the observations and evaluations described herein have resulted in timely implementation of needed changes to improve the design, construction and maintenance of Caltrans' edge drains.

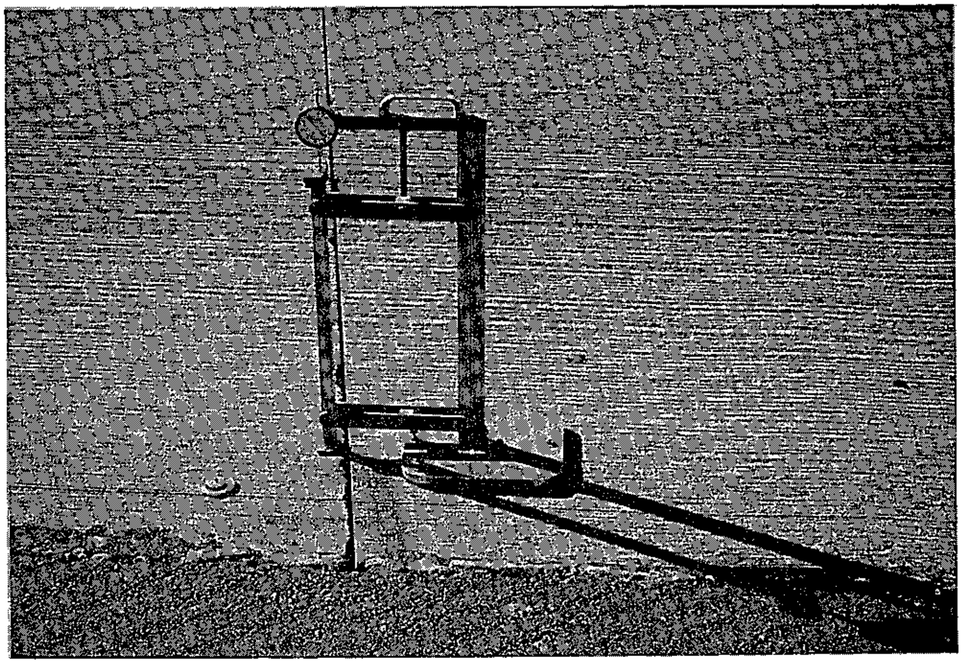


Photo No. 1 - Fault Measurement
Gauge

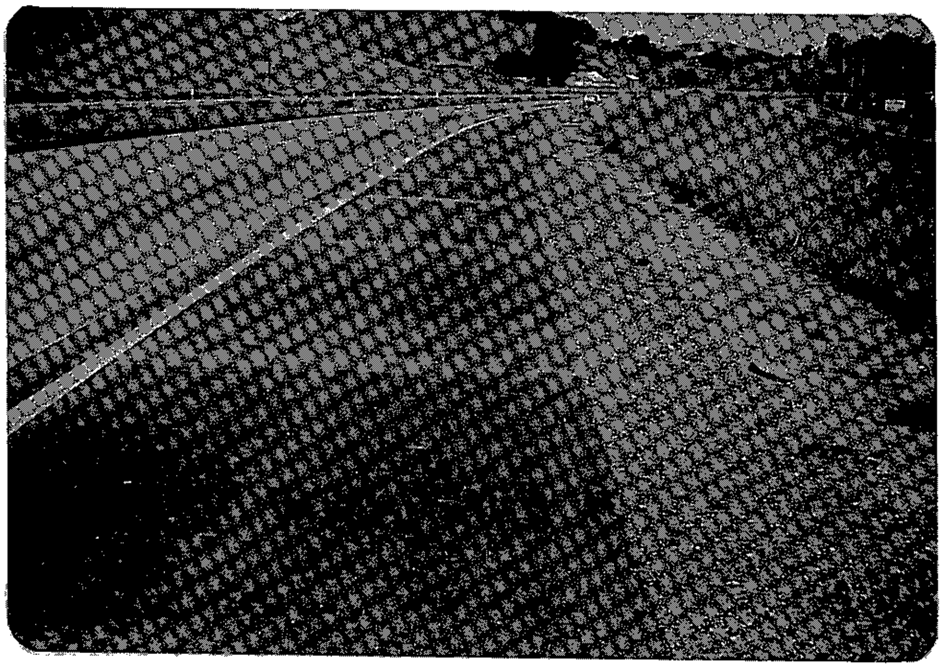


Photo No. 2 - Pumping Stains on
Control (No Edge Drain) Section Shoulder

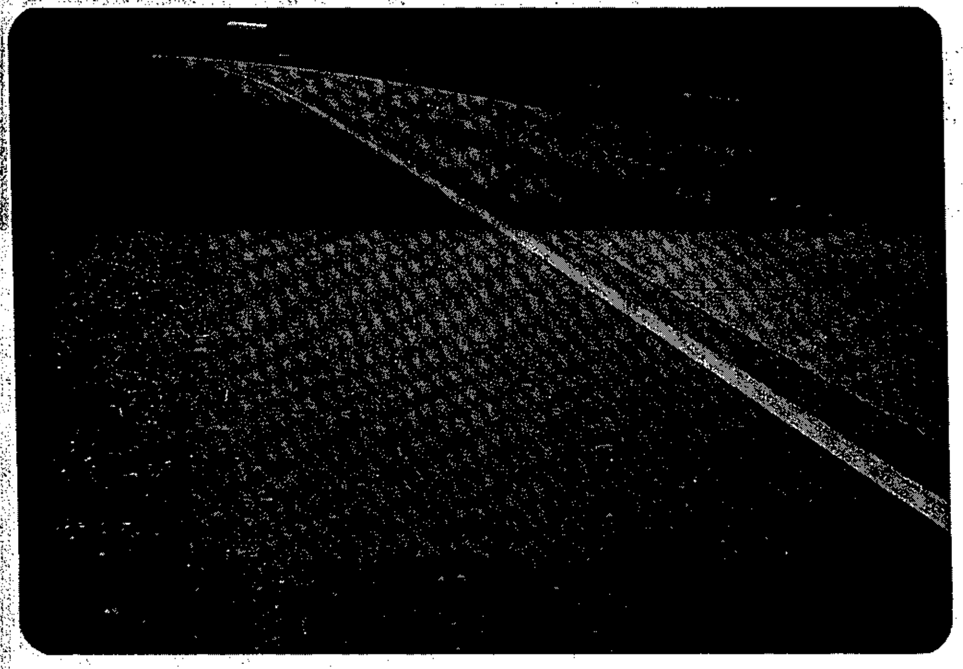


Photo No. 3 - No Pumping Stains or Trench Depression Over CTPM Edge Drain Section

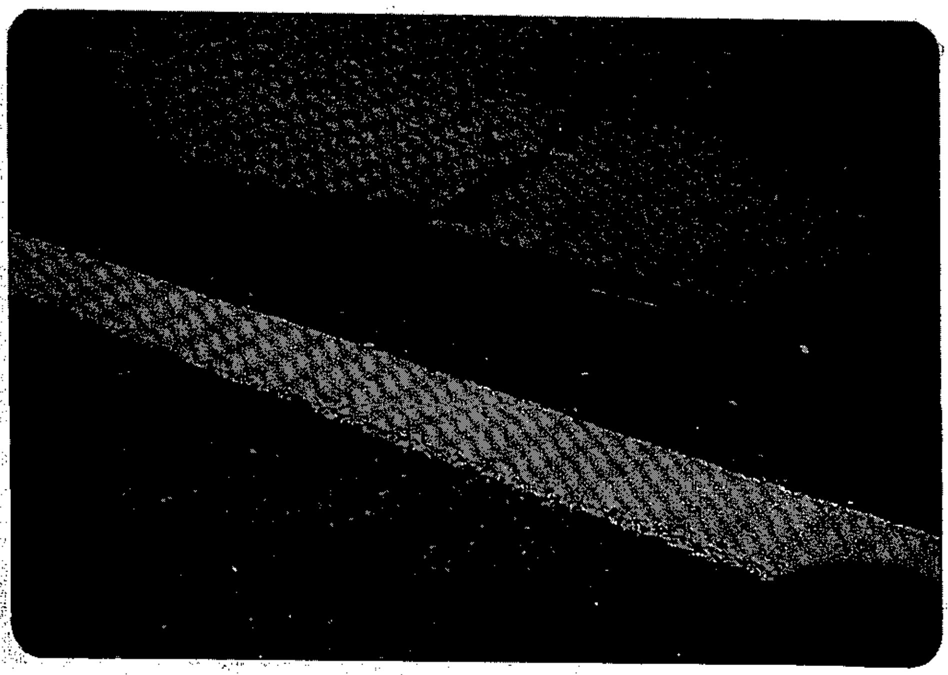


Photo No. 4 - Depression in Trench Where UTPM was Used

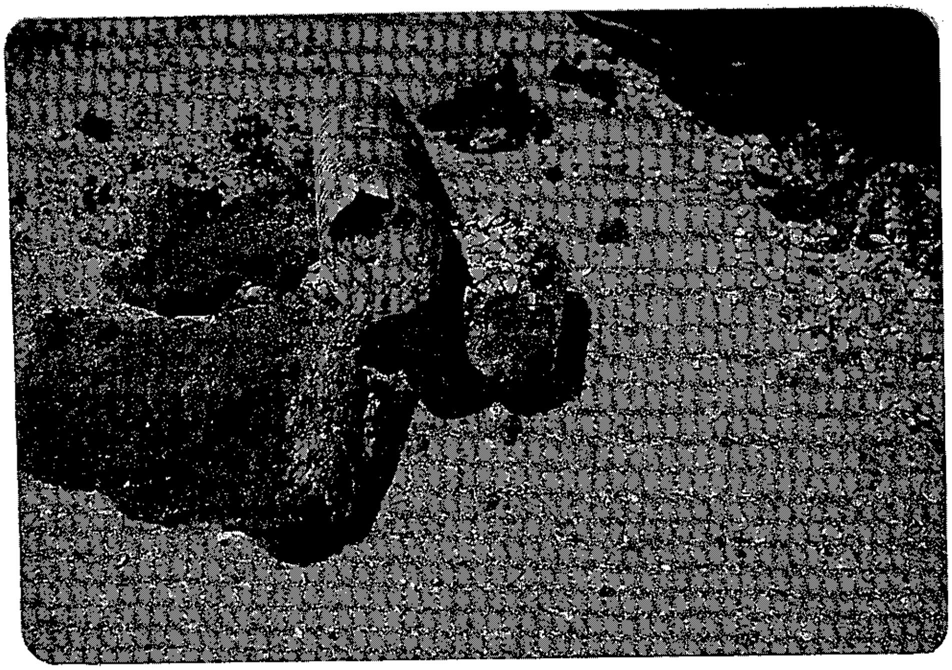


Photo No. 5 - Plugged Edge Drain

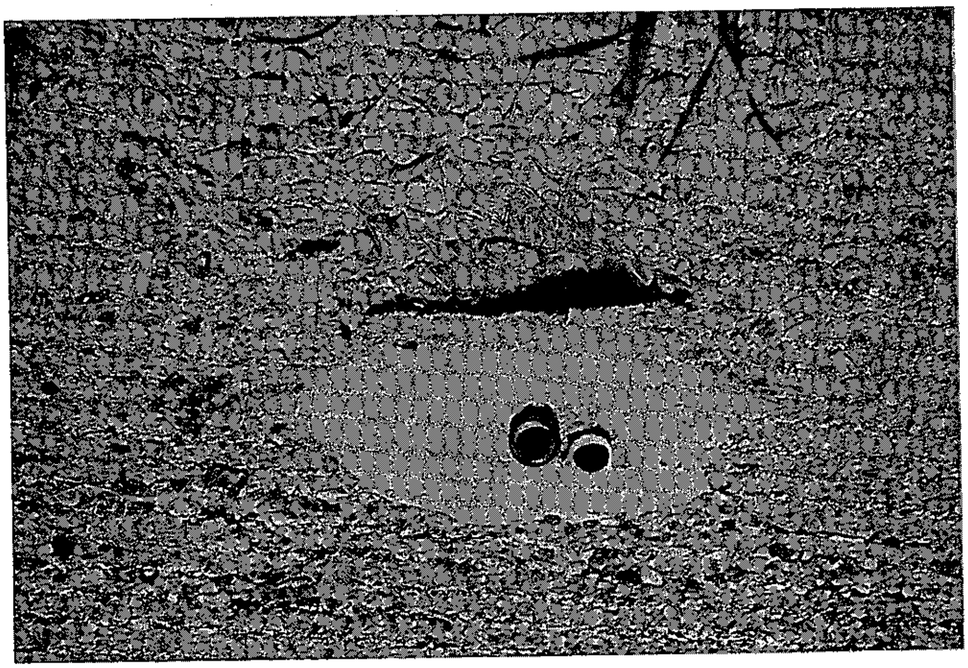


Photo No. 6 - Splash Pad Erosion

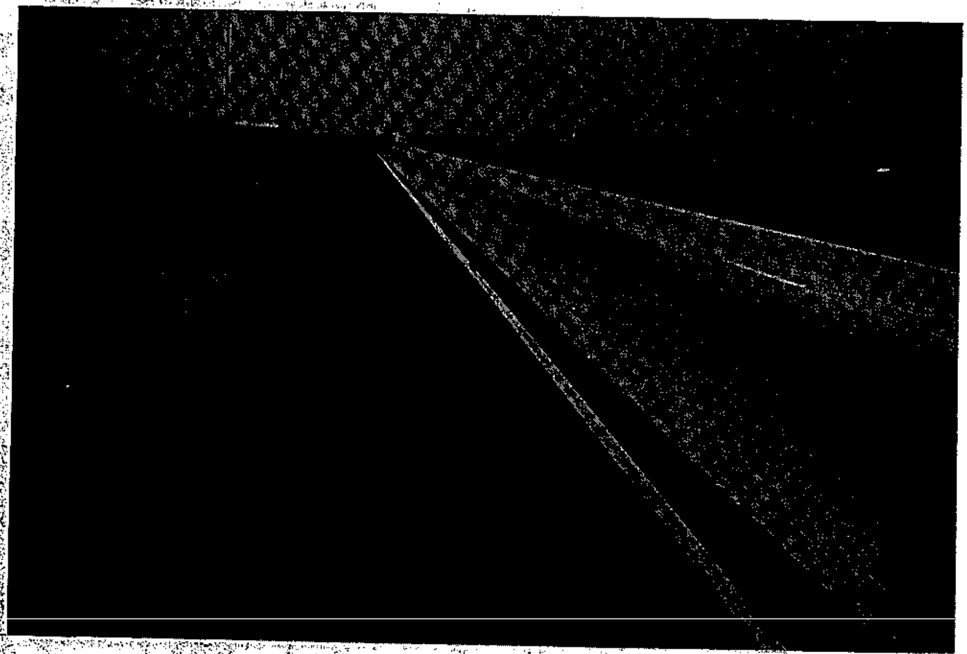


Photo No. 7 - Pumping Stains on Control Section Shoulder with LCB

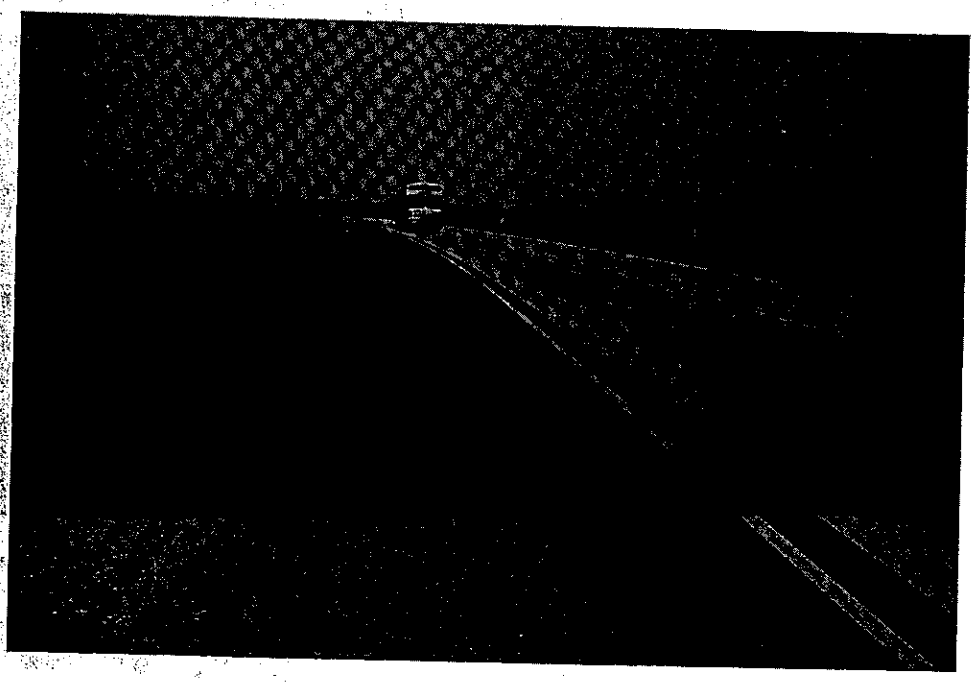


Photo No. 8 - No Pumping Stains or Shoulder Deterioration Over New Construction Edge Drain with LCB

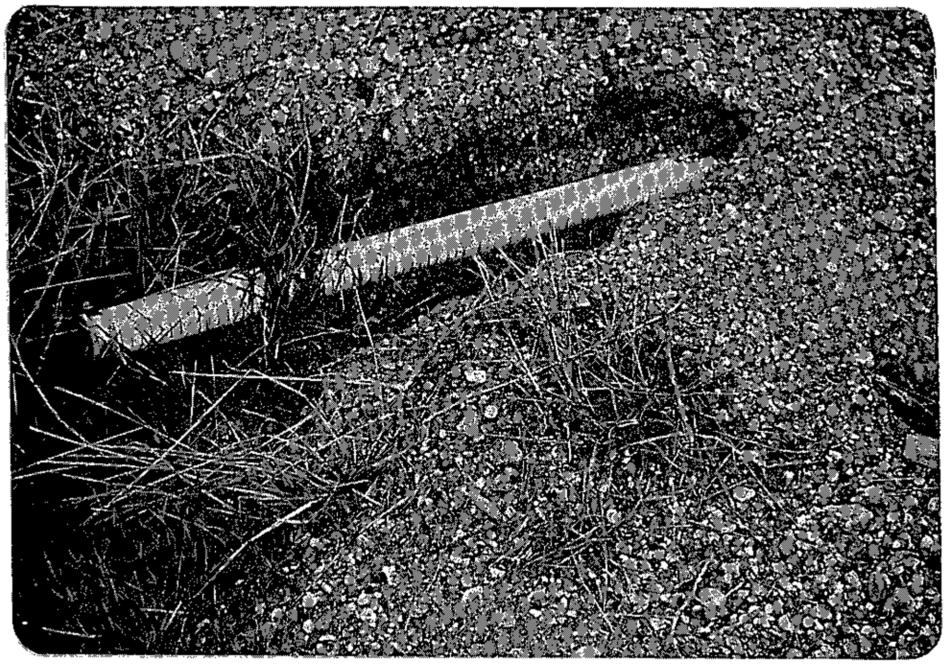


Photo No. 9 - Slotted Outlet Pipe Erosion

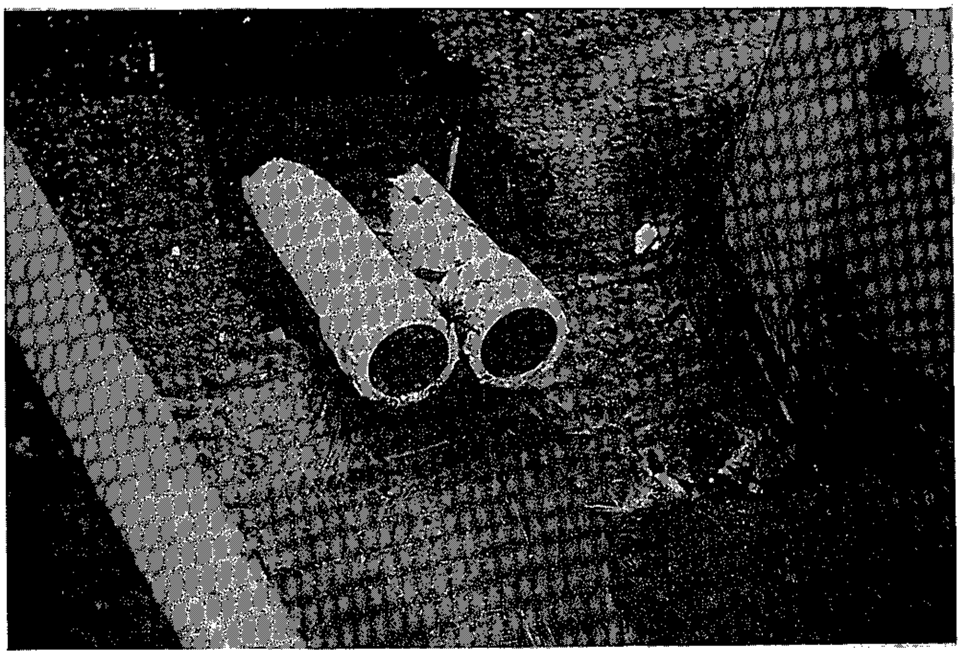


Photo No. 10 - Plugged Screens

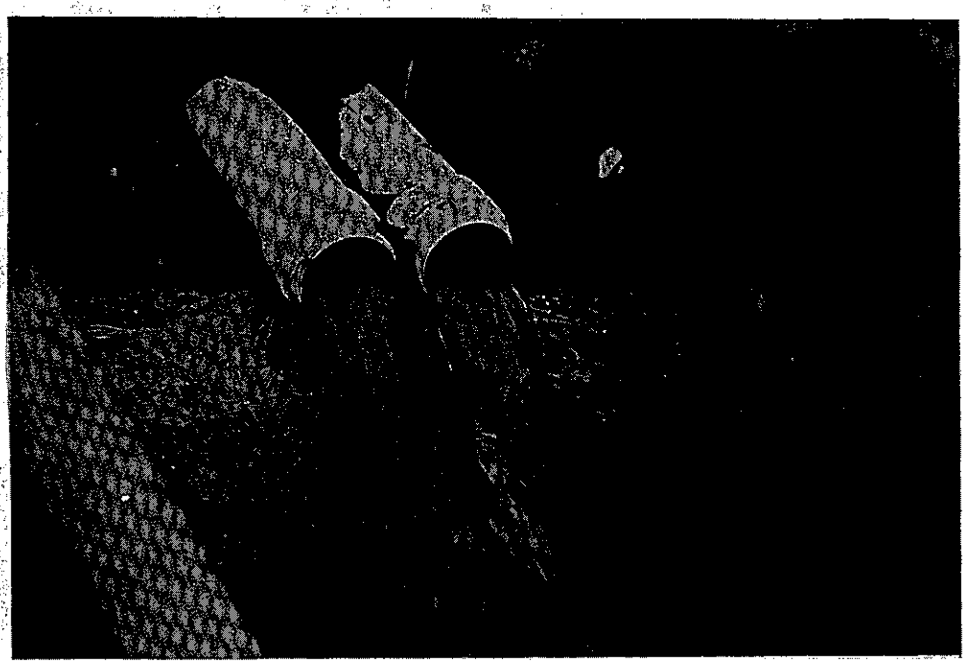


Photo No. 11 - Screens Removed

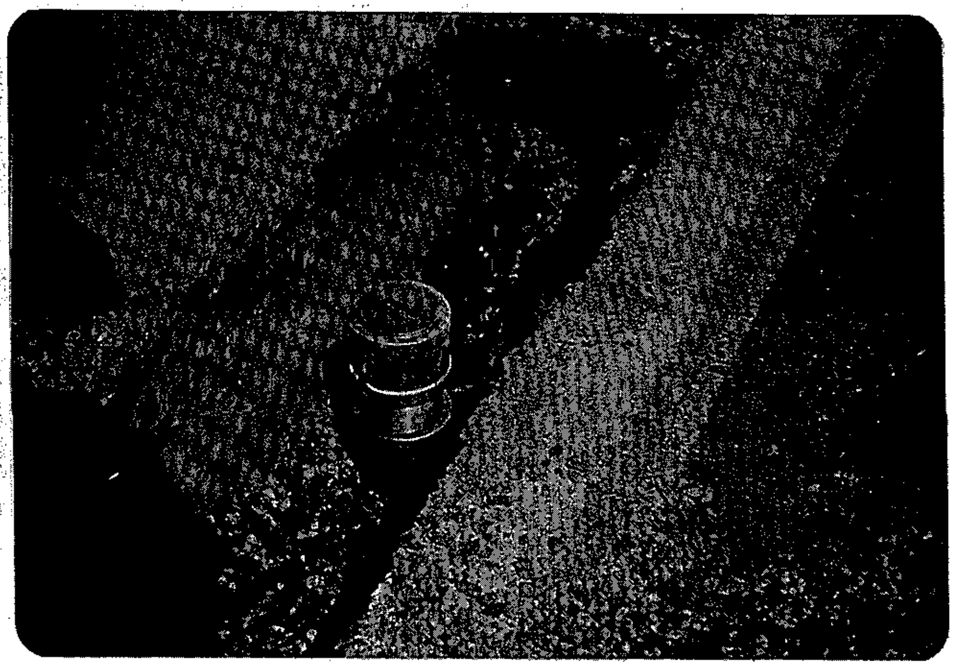


Photo No. 12 - Retrofit Cleanout for "L" Type System

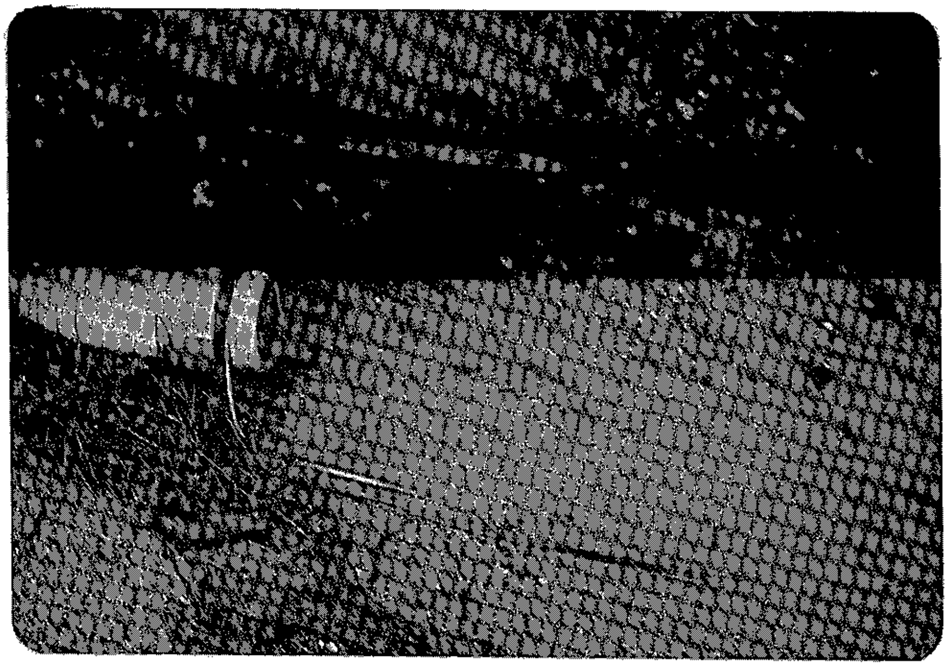


Photo No. 13 - Drainage Before Cleaning

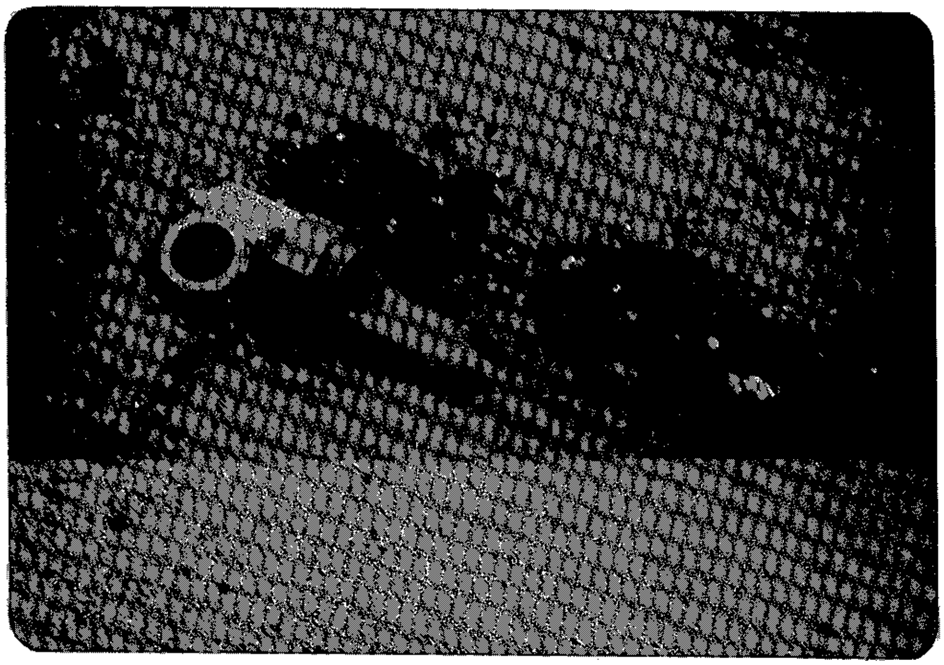


Photo No. 14 - Drainage After Cleaning

REFERENCES

Cited

1. Spellman, D. L.; Woodstrom, J. H. and Neal, B. F., Faulting of Portland Cement Concrete Pavements, Caltrans, publication No. M&R HRB 635167, August 1971.

2. Neal, B. F., Model Slab Faulting Study, Caltrans, publication No. FHWA/CA/TL-80/23, June 1980.

Uncited

3. Cedergren, H. R., O'Brien, K. H. and Arman, J. A., Guidelines For the Design of Subsurface Drainage Systems for Highway Structural Sections, FHWA Report No. FHWA-RD-72-30, June 1972.

APPENDIX 1

Standard Specification 68-3, Edge Drains

Section 4-1.03D.

68-3 EDGE DRAINS

68-3.01 Description.—This work shall consist of furnishing and installing plastic pipe edge drains and edge drain outlets, vents, and cleanouts, and furnishing and placing treated permeable material, filter fabric and miscellaneous appurtenances as shown on the plans and as specified in these specifications and the special provisions.

68-3.02 Materials.—The materials for edge drains shall conform to the following:

68-3.02A Pipe and Pipe Fittings.—Pipe for edge drains and edge drain outlets, vents, and cleanouts shall be 2-inch nominal size, and shall, at the Contractor's option, be either Schedule 40 or Schedule 80 polyvinyl chloride (PVC) plastic pipe conforming to the requirements of ASTM Designation: D 1785. The type, grade, and design stress designation of the pipe shall, at the Contractor's option, be either 1120, 1220, 2120, 2116, 2112, or 2110 as specified in said ASTM Designation.

In addition, pipe designated as slotted on the plans shall have 3 rows of slots in the pipe. The rows shall be in the longitudinal direction of the pipe and the slots shall be cut in the circumferential direction of the pipe. The 3 rows shall be spaced equally around the circumference of the pipe. Each row shall have 22(±1) uniformly spaced slots per linear foot of pipe. The slots shall be 0.050-inch wide and of such length as to provide a minimum of 2.00 square inches of slot opening per linear foot of pipe. Other suitable configurations of slots which provide drainage equal to or better than the above slot requirements may be used if approved in writing by the Engineer.

Fittings shall be socket-type fittings conforming to the requirements of ASTM Designation: D 2467 for Schedule 80 pipe and ASTM Designation: D 2466 for Schedule 40 pipe.

Edge drain outlet and vent covers shall consist of commercial quality ⅜ inch mesh galvanized metal screens or grates with polyvinyl chloride slip joint nut fittings. The outlet and vent covers shall be installed at the end of each outlet pipe and vent pipe.

68-3.02B Treated Permeable Material.—Permeable material for edge drains shall be either asphalt treated or cement treated. The type of treatment to be used shall be at the option of the Contractor.

68-3.02B(1) Asphalt Treated Permeable Material.—Asphalt treated permeable material shall consist of a mixture of coarse aggregate and asphalt binder.

The aggregate for asphalt treated permeable material shall be clean and free from decomposed materials, organic material and other deleterious substances, and shall conform to one of the following gradings:

Sieve Sizes	*Percentage Passing* ¾" *Max.*	½" *Max.*
1"	100	-
¾"	50–100	100
½"	-	50–100
⅜"	15–85	15–100
No. 4	0–5	0–5

The aggregate shall conform to the following quality requirements:

Test	*California Test*	*Requirement*
Crushed Particles	205	25% Min.
Loss in Los Angeles Rattler (after 500 revolutions)	211	50% Max.
Durability Index	229	40 Min.
Film Stripping	302	25% Max.

California Tests 205, 211, and 229 will be performed prior to mixing the aggregate with asphalt. California Test 302 will be performed after mixing the aggregate with asphalt.

Asphalt binder to be mixed with the aggregate shall be paving asphalt Grade AR-8000 or AR-4000 conforming to the requirements in Section 92, "Asphalts."

The aggregate shall be treated with 2 percent of paving asphalt by weight of the dry aggregate. Not less than 95 percent of the aggregate shall be coated.

Asphalt treated permeable material shall be mixed at a central mixing plant, and shall be stored, proportioned and mixed in accordance with the provisions for storing, proportioning and mixing Open Graded asphalt concrete in Section 39-3, "Storing, Proportioning and Mixing Materials."

68-3.02B (2) Cement Treated Permeable Material.—Cement treated permeable material shall consist of a mixture of coarse aggregate, portland cement and water conforming to the provisions for portland cement concrete in Sections 90-1, "General," 90-2, "Materials," 90-3, "Aggregate Gradings," 90-4, "Admixtures," 90-5, "Proportioning," and 90-6, "Mixing and Transporting," and these specifications.

The aggregate shall conform to the 1" x No. 4 primary aggregate grading specified in Section 90-3.02, "Coarse Aggregate Grading."

Not less than 282 pounds of cement shall be used for each cubic yard of cement treated permeable material produced. The water-cement ratio shall be approximately 0.43. The exact water-cement ratio will be determined by the Engineer.

68-3.02C Filter Fabric.—Filter fabric shall conform to the provisions in Section 88, "Engineering Fabrics."

68-3.02D Miscellaneous.—Concrete for splash pads shall be produced from commercial quality aggregates and cement and shall contain not less than 470 pounds of cement per cubic yard.

Mortar placed where edge drain outlets and vents connect to drainage pipes and existing drainage inlets shall conform to the provisions in Section 51-1.135, "Mortar," except that the sand and cement shall be commercial quality.

Cleanout assemblies and covers shall conform to the details shown on the plans and shall be cast iron conforming to the requirements in Section 75, "Miscellaneous Metal." Concrete encasement for cleanout assemblies shall be minor concrete conforming to the requirements in Section 90-10, "Minor Concrete," except that the cement content shall be not less than 658 pounds per cubic yard.

68-3.03 Installation.—Edge drains, edge drain outlets, vents, and cleanouts, treated permeable material, and filter fabric shall be installed in accordance with the details shown on the plans and as specified in this Section 68-3.03.

Prior to excavating trenches for the installation of edge drains and edge drain outlets, vents and cleanouts in existing paved areas, the outline of the paved areas to be removed shall be cut to a neat line to a minimum depth of 2 inches with a power-driven saw or a wheel type rock cutting excavator. Cuts along the joint between existing asphalt concrete and existing portland cement concrete pavement will not be required.

Surfaces to receive filter fabric, immediately prior to placing, shall be free of loose or extraneous material and sharp objects that may damage the filter fabric during installation.

The fabric shall be stretched, aligned and placed in a wrinkle-free manner.

Adjacent rolls of the fabric shall be overlapped from 12 to 18 inches. The preceding roll shall overlap the following roll in the direction the material is being spread.

Should the fabric be damaged during placing, the torn or punctured section shall be either completely replaced or shall be repaired by placing a piece of fabric that is large enough to cover the damaged area and to meet the overlap requirement.

Damage to the fabric resulting from the Contractor's vehicles, equipment or operations shall be replaced or repaired by the Contractor at his expense.

Pipe and fittings shall be joined by solvent cementing with commercial quality solvent cement and primer specifically manufactured for use with rigid PVC plastic pipe and fittings. The solvent cement and primer used shall be made by the same manufacturer. The color of the primer shall contrast with the color of the pipe and fittings. The solvent cement and primer shall be used in accordance with the manufacturer's printed instructions.

Asphalt treated permeable material shall be placed at a temperature of not less than 180° F. nor more than 230° F.

Asphalt treated permeable material may be spread in one layer. It shall be compacted with a vibrating shoe type compactor or rolled with a roller weighing not less than 1½ tons nor more than 5 tons as soon as the mixture has cooled sufficiently to take the weight of the compacting equipment without undue displacement.

Cement treated permeable material may be spread in one layer. The material shall be compacted within one hour of placing with either a vibrating shoe type compactor or with a steel-drum roller weighing not less than 1½ tons nor more than 5 tons.

Cement treated permeable material, which is not covered with asphalt concrete within 12 hours after compaction of the permeable material, shall be cured by either sprinkling the material with a fine spray of water every 4 hours during daylight hours or covering the material with a white polyethylene sheet, not less than 6 mils thick. The above curing requirements shall begin at 7:00 a.m. on the morning following compaction of the cement treated permeable material and continue for the next 72 hours or until the material is covered with asphalt concrete, whichever is less. The cement treated permeable material shall not be sprayed with water during the first 12 hours after compacting, but may be covered with the polyethylene sheet during the first 12 hours or prior to the beginning of the cure period.

Trenches in existing embankment areas shall be backfilled with native material and compacted as directed by the Engineer.

Aggregate base for backfilling trenches in existing paved areas shall be produced from commercial quality aggregates consisting of broken stone; crushed gravel; natural, clean, rough-surfaced gravel or sand; or a combination thereof. The aggregate shall be free from organic material and other deleterious substances and shall conform to the ¾ inch maximum grading specified in Section 26-1.02B, "Class 2 Aggregate Base."

Aggregate base backfill shall be spread and compacted by methods that will produce a uniform base, firmly compacted, and free from pockets of coarse or fine material.

Asphalt concrete for backfilling trenches in existing paved areas shall be produced from commercial quality aggregates and asphalt and mixed at a central mixing plant. The aggregate shall conform to the ¾ inch maximum coarse or medium grading, or the ½ inch maximum coarse or medium grading specified in Section 39-2.02, "Aggregate." The amount of asphalt binder to be mixed with the aggregate shall be between 4 percent and 7 percent by weight of the dry aggregate, as determined by the Engineer.

Asphalt concrete backfill shall be spread and compacted in 2 layers by methods that will produce an asphalt concrete surfacing of uniform smoothness, texture, and density.

Surplus excavated material shall become the property of the Contractor and shall be disposed of outside the highway right of way in accordance with the provisions in Section 7-1.13.

Type A pavement markers conforming to the details shown on the plans and the provisions in Section 85, "Pavement Markers," shall be placed on paved shoulders at outlet, vent, and cleanout locations as directed by the Engineer. Pavement markers shall be cemented with Standard Set Type adhesive or Rapid Set Type adhesive. The 14-day waiting period for placing pavement markers on new asphalt concrete surfacing will not apply.

The edge drain and edge drain outlet, vent, and cleanout pipes shall be clean at the time of installation and shall be free of obstructions after installation. The Contractor may use any method satisfactory to the Engineer to verify the pipes are free of obstructions.

68-3.04 Measurement.—Edge drains and edge drain outlets, vents, and cleanouts will be measured by the linear foot along the line of the pipe. The length to be paid for will be the slope length of the pipe designated by the Engineer. Pipe placed in excess of the length designated by the Engineer will not be paid for. Outlet pipe, vent pipe and cleanout pipe will be measured and paid for as 2-inch plastic pipe (edge drain outlet).

No deduction in the length of 2-inch plastic pipe (edge drain) will be made for gaps in edge drain pipe at locations of dual outlet, dual vent, or dual outlet and vent connections to the edge drain.

The "Y" fitting at cleanout pipes will be measured and paid for as 2-inch plastic pipe (edge drain outlet) between the couplings at each end of the curved section of the "Y" fitting, and as 2-inch plastic pipe (edge drain) between the couplings at each end of the straight section of the "Y" fitting.

Quantities of cleanout assemblies will be determined as units from actual count.

68-3.05 Payment.—The contract price paid per linear foot for 2-inch plastic pipe (edge drain) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in constructing edge drains complete in place, including excavation (and removal of any concrete deposits that may occur along the lower edge of the concrete pavement in Type 1 installations) and asphalt concrete backfill for Type 1 edge drain installation, filter fabric, and treated permeable material, as shown on the plans, as specified in these specifications and the special provisions, and as directed by the Engineer.

The contract price paid per linear foot for 2-inch plastic pipe (edge drain outlet) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in constructing edge drain outlets, vents, and cleanouts (except cleanout assemblies) complete in place, including outlet and vent covers, pavement markers, concrete splash pads, connecting outlets and vents to drainage facilities, and excavation and backfill (aggregate base, asphalt concrete, and native material) for outlets, vents, and cleanouts to be installed in embankments and existing shoulders, as shown on the plans, as specified in these specifications and the special provisions, and as directed by the Engineer.

The contract unit price paid for cleanout assembly (edge drain) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing cleanout assemblies complete in place, including concrete encasement, and any necessary structure excavation or backfill, as shown on the plans, as specified in these specifications and the special provisions, and as directed by the Engineer.

APPENDIX 2

Standard Special Provision 68.20, Edge Drains

(Paras. 4, 6 and 8 are new.)

68.20
10-17-84

10-1.__ EDGE DRAINS.--Edge drains shall conform to the requirements in Section 68-3, "Edge Drains," of the Standard Specifications and these special provisions.

The first paragraph in Section 68-3.02A, "Pipe and Pipe Fittings," of the Standard Specifications is amended to read: 2

Pipe for edge drains and edge drain outlets, vents, and cleanouts shall be 2-inch nominal size, and shall, at the Contractor's option, be either Schedule 40 or Schedule 80 polyvinyl chloride (PVC) plastic pipe conforming to the requirements of ASTM Designation: D 1785. Pipe shall be straight end or bell end. Bell end pipe shall conform to the requirements of ASTM Designation: D 2672 except for marking. The type, grade, and design stress designation of the pipe shall, at the Contractor's option, be either 1120, 1220, 2120, 2116, 2112, or 2110 as specified in said ASTM Designations. 2a

The third paragraph in Section 68-3.02A, "Pipe and Pipe Fittings," of the Standard Specifications is amended to read: 3

Fittings, except for "Y" fittings, shall be socket-type fittings conforming to the requirements of ASTM Designation: D 2467 for Schedule 80 pipe and ASTM Designation: D 2466 for Schedule 40 pipe. "Y" fittings shall be shop fabricated from pipe conforming to the requirements for edge drain outlet pipe. The fitting shall provide an unobstructed passageway through both legs of the "Y". 3a

The third paragraph in Section 68-3.02B(2), "Cement Treated Permeable Material," of the Standard Specifications is amended to read: 4

Not less than 282 pounds of cement shall be used for each cubic yard of cement treated permeable material produced. The water-cement ratio shall be approximately 0.37. The exact water-cement ratio will be determined by the Engineer. 4a

The fourth paragraph in Section 68-3.03, "Installation," of the Standard Specifications is amended to read: 5

The fabric shall be aligned and placed in a wrinkle-free manner. 5a

The last paragraph in said Section 68-3.03 is amended to read: 6

The edge drain outlet, vent and cleanout pipes shall be clean at the time of installation and shall be free of obstructions after installation. The Contractor shall use a nominal one inch diameter, high pressure, flexible hose with a nozzle containing flushing and propelling jets. The hose shall be inserted into each edge drain outlet, vent and cleanout pipe and pushed through the pipe with a minimum 200 PSIG water pressure so that the entire edge drain system shall be penetrated by the flushing nozzle. Pipes that are found to be plugged shall be replaced by the Contractor at his expense, including replacement of permeable material, surfacing or backfill materials. 6a

The "Y" fitting at intermediate outlet connections will be measured and paid for in the same manner as provided for "Y" fittings at cleanout pipes in Section 68-3.04, "Measurement," of the Standard Specifications. 7

Wherever 2-inch plastic pipe is referred to in said Section 68-3 of the Standard Specifications or on the Standard Plans with reference to edge drains, it shall be deemed to mean the size of plastic pipe designated in the contract item. 8

APPENDIX 3

Standard Special Provision 68.25, Filter Fabric

(Paras. 14 and 15 revised to make measurement by the square yard.)

10-1.____ FILTER FABRIC.--Filter fabric shall be placed where shown on the plans and at locations designated by the Engineer in accordance with the requirements in these special provisions.

Filter fabric shall be manufactured from one or more of the following materials: polyester, nylon or polypropylene. 2

Filter fabric shall be nonwoven, shall not act as a wicking agent, shall be permeable and shall conform to the following: 3

Characteristic	ASTM Designation	Requirement
Weight, ounces per square yard	D 1910	4.0 Min.
Grab Tensile Strength (1-inch grip), pounds	D 1682	100 Min. (in each direction)
Elongation, percent	D 1682	50 Min.
Toughness, pounds	(Percent elongation x Tensile strength)	6,000 Min.

The filter fabric shall be furnished in an appropriate protective cover which shall protect it from ultraviolet radiation and from abrasion due to shipping and handling. 4

Filter fabric shall be accompanied by a Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications. 5

The subgrade to receive the filter fabric, immediately prior to placing, shall conform to the compaction and elevation tolerance specified for the material involved and shall be free of loose or extraneous material and sharp objects that may damage the filter fabric during installation. 6

Filter fabric shall be handled and placed in accordance with the manufacturer's recommendations. 7

The fabric shall be stretched, aligned and placed in a wrinkle-free manner. 8

Adjacent borders of the fabric shall be overlapped from 12 to 18 inches or stitched. The preceding roll shall overlap the following roll in the direction the material is being spread or shall be stitched. When the fabric is joined by stitching, it shall be stitched with yarn of a contrasting color. The size and composition of the yarn shall be as recommended by the fabric manufacturer. The stitches shall number 5 to 7 per inch of seam. 9

Within 24 hours after the filter fabric has been placed, it 10
shall be covered with the planned thickness of permeable material or aggregate subbase material as shown on the plans.

Should the fabric be damaged during placing, the torn or 11
punctured section shall be repaired by placing a piece of fabric that is large enough to cover the damaged area and to meet the overlap requirement.

Damage to the fabric resulting from the Contractor's 12
vehicles, equipment or operations shall be repaired by the Contractor at his expense.

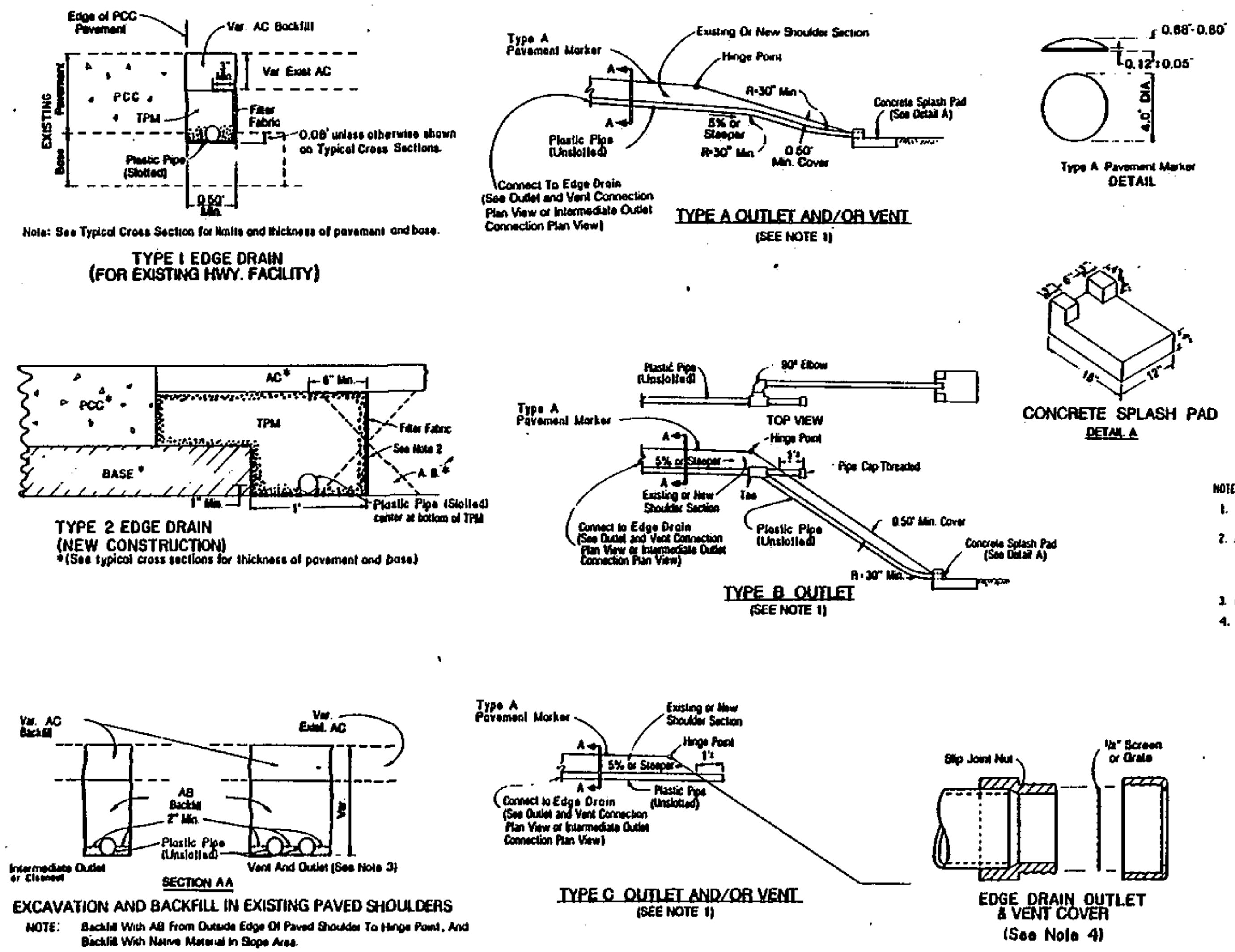
During spreading and compaction of the permeable material and 13
aggregate subbase material, a minimum of 6 inches of such material shall be maintained between the fabric and the Contractor's equipment. Where embankment material is to be placed on the filter fabric, a minimum of 18 inches of embankment material shall be maintained between the fabric and the Contractor's equipment. Equipment or vehicles shall not be operated or driven directly on the filter fabric.

The quantity of filter fabric to be paid for will be measured 14
by the square yard of area covered, not including additional fabric for overlap.

The contract price paid per square yard for filter fabric 15
shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in placing the filter fabric, complete in place, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

APPENDIX 4

Revised Standard Plan RSP-D98-D,
Subgrade Drain Details



To Accompany Plans Dated ______

ABBREVIATIONS

AB — Aggregate Base
AC — Asphalt Concrete
PCC — Portland Cement Concrete
TPM — Treated Permeable Material
ETW — Edge of Traveled Way
ES — Edge of Shoulder

NOTES:

1. See Project Plans for typical cross-sections and location and type of outlet and vent installation.
2. At the Contractor's option on new construction (Type 2 Edge Drain), the vertical joint line (including filter fabric) between the TPM and AB may be rotated about its midpoint to a slope not flatter than 1:1 in either direction as shown by dashed lines.
3. Details shown also apply to dual outlet or dual vent installations.
4. Outlet and vent covers to be installed when required by the special provisions.

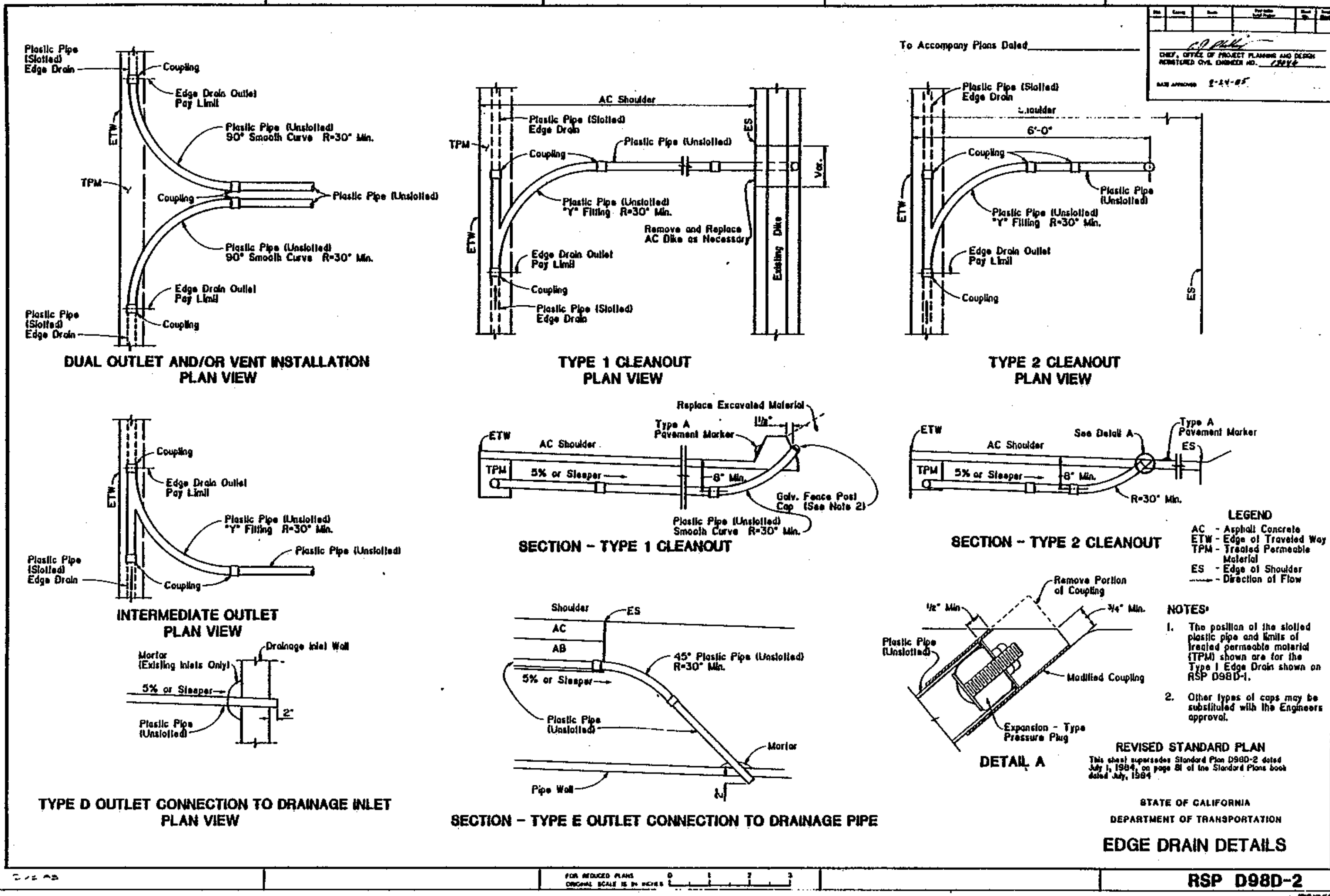
REVISED STANDARD PLAN

This sheet supersedes Standard Plan D98D-1 dated July 1, 1984, on page 80 of the Standard Plans book dated July, 1984

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

EDGE DRAIN DETAILS

RSP D98 D-1



RSP D98D-2
To Accompany Plans Dated
CHIEF, OFFICE OF PROJECT PLANNING AND DESIGN
REGISTERED CIVIL ENGINEER NO.
DUAL OUTLET AND/OR VENT INSTALLATION
PLAN VIEW
Plastic Pipe (Slotted) Edge Drain
Coupling
Edge Drain Outlet Pay Limit
Plastic Pipe (Unslotted) 90° Smooth Curve R=30" Min.
Plastic Pipe (Unslotted)
ETW
TPM
TYPE 1 CLEANOUT
PLAN VIEW
AC Shoulder
Plastic Pipe (Unslotted) "Y" Fitting R=30" Min.
Remove and Replace AC Dike as Necessary
Existing Dike
ES
Var.
TYPE 2 CLEANOUT
PLAN VIEW
Shoulder
6'-0"
INTERMEDIATE OUTLET
PLAN VIEW
SECTION - TYPE 1 CLEANOUT
Replace Excavated Material
Type A Pavement Marker
1½"
5% or Sleeper
8" Min.
Galv. Fence Post Cap (See Note 2)
Plastic Pipe (Unslotted) Smooth Curve R=30" Min.
SECTION - TYPE 2 CLEANOUT
See Detail A
R=30" Min.
LEGEND
AC - Asphalt Concrete
ETW - Edge of Traveled Way
TPM - Treated Permeable Material
ES - Edge of Shoulder
- Direction of Flow
TYPE D OUTLET CONNECTION TO DRAINAGE INLET
PLAN VIEW
Mortar (Existing Inlets Only)
Drainage Inlet Wall
2"
SECTION - TYPE E OUTLET CONNECTION TO DRAINAGE PIPE
AB
45° Plastic Pipe (Unslotted) R=30" Min.
Mortar
Pipe Wall
DETAIL A
Remove Portion of Coupling
½" Min.
¾" Min.
Modified Coupling
Expansion - Type Pressure Plug
NOTES:
1. The position of the slotted plastic pipe and limits of treated permeable material (TPM) shown are for the Type I Edge Drain shown on RSP D98D-1.
2. Other types of caps may be substituted with the Engineers approval.
REVISED STANDARD PLAN
This sheet supersedes Standard Plan D98D-2 dated July 1, 1984, on page 81 of the Standard Plans book dated July, 1984
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
EDGE DRAIN DETAILS
RSP D98D-2
FOR REDUCED PLANS ORIGINAL SCALE IS IN INCHES
0 1 2 3

APPENDIX 5

Result of Value Engineering Study on
Edge Drain Clean-Out Assemblies

State of California

Business, Transportation
and Housing Agency

MEMORANDUM

Date: February 15, 1985

To: Al Philips, Chief
Office of Project
Planning and Design

File:

Attention: Wally Ames

From: DEPARTMENT OF TRANSPORTATION - Value Engineering
and Resource Conservation Branch

Sub: Correction to V.E. Study of Edge Drain Cleanout Assemblies, Dec. 198

The above referenced report should be corrected as follows:

- Page 1 (Introduction, first paragraph) should read, "(Refer to Standard Plan D98D-2, Exhibit A)." instead of D98D-1.
- Page 2 (exhibit A) should be sheet D98D-2 of the Standard Plans instead of D98D-1.
- Page 3 (Recommendations, paragraph 2) should read, "If these items are verified, modify Standard Plans sheet D98D-2 accordingly." instead of D98D-1.

Please replace pages 1, 2, and 3 with the attached pages.

If there are any questions please call:

Brian Lee	(916) 324-7213	ATSS 454-7213 or
Marty VanZandt	(916) 445-2164	ATSS 485-2164.

E. D. Spartz

Darwin Spartz, Chief
Value Engineering, Branch

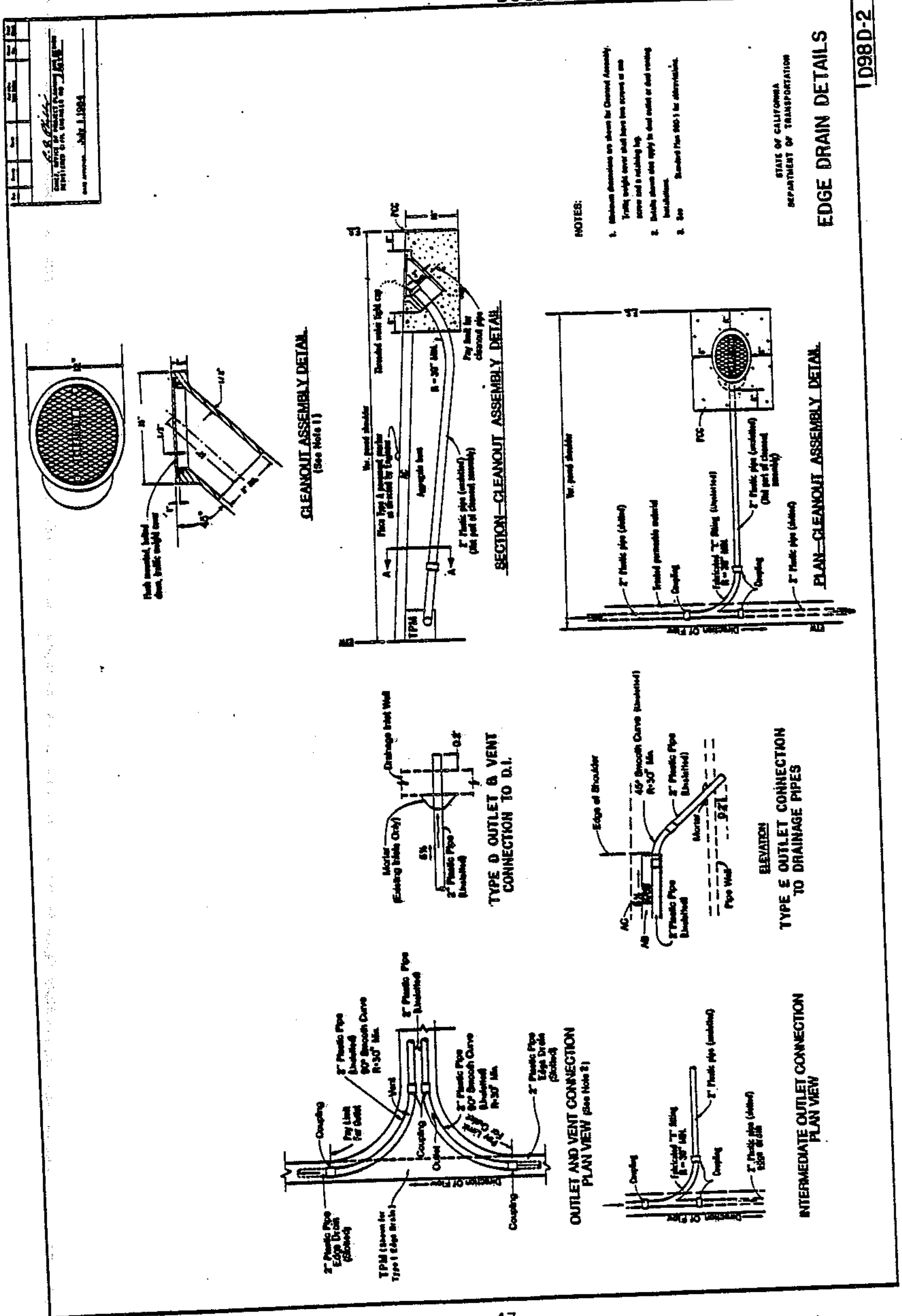
cc: see attached list

I. INTRODUCTION

This study resulted from a request by Bob Gillispie, Construction Branch A, District 10, to the Office of Value Engineering and Productivity Management to perform a value analysis on the high cost of edgedrain cleanout assemblies (COA's). COA's are access openings to edge drain systems. The current design consists of a cast iron collar with screw down cover plate set into a concrete block. COA's are generally constructed in the outer shoulder, 1 foot inside the edge of shoulder (Refer to Standard Plan D98D-2, Exhibit A). COA's are normally used in edge drain systems when the roadway is in a cut section and outlets are spaced at distances which exceed Maintenance's ability to clean them (generally in excess of 200-300 feet).

The structured value engineering process was followed through all phases of the study to develop alternative solutions. Informal meetings were held with management during the process and a formal presentation made to representatives of Construction, Design, Maintenance, Translab, etc. on May 18, 1984. These Caltrans managers accepted the alternative proposals and the suggestion that a sample proposal be constructed on an ongoing construction project. This was accomplished on 8/3/84 on Route 5 near Santa Nella, 10-Mer-5-8.0/32.5, at approximate post mile 28.3 to 29.0 (southbound).

D98D-2


D98D-2
EDGE DRAIN DETAILS
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
NOTES:
CLEANOUT ASSEMBLY DETAIL
SECTION—CLEANOUT ASSEMBLY DETAIL
PLAN—CLEANOUT ASSEMBLY DETAIL
TYPE D OUTLET & VENT CONNECTION TO D.I.
ELEVATION
TYPE E OUTLET CONNECTION TO DRAINAGE PIPES
OUTLET AND VENT CONNECTION PLAN VIEW
INTERMEDIATE OUTLET CONNECTION PLAN VIEW

II. RECOMMENDATIONS

A. The V.E. study team recommends the Office of Project Planning and Design (OPPD) implement the following actions:

- C.O.A.'s TYPE 10 and TYPE 20 (herein proposed) be constructed on several future projects to verify ease of construction, estimate of cost, and to evaluate performance. If these items are verified, modify Standard Plans sheet D-98D-2 accordingly.

- Work with the Office of Office Engineer to revise section 68.20 of the Standard Special Provisions (see Exhibit C) to correspond to revisions mentioned above.

Exhibits B and C are provided as suggested revisions and should be reviewed by OPPD for completeness and accuracy before implementation.

B. Other considerations which came to our attention are listed below along with our recommendations for disposition:

1. General lack of uniformity in design standards concerning the placement of C.O.A.'s.

   Recommendation: The OPPD should issue a Design Information Bulletin adopting the following guidelines:

   - Outlet spacing not to exceed 200 feet (excluding transverse outlet length).

   - TYPE 10 C.O.A.'s to be constructed only if TYPE A-E outlets are inappropriate.

   - TYPE 20 C.O.A.'s to be constructed only if TYPE A-E outlets and TYPE 10 C.O.A.'s are inappropriate.

2. Are rodent protection covers (inhibitors) always necessary on vents and outlets (see Exhibit A)? Are there other solutions?

   Recommendation: The OPPD has already initiated a request to investigate this problem. A study has been completed by the Value Engineering and Resource Conservation Branch. Inhibitors may not be needed in all cases. There are better value rodent exclusion methods than the screens currently used.

APPENDIX 6

Retrofit Edge Drain Prioritization for
Caltrans Office of Highway Maintenance

State of California

Memorandum

Date: March 2, 1982

File :

To : E. B. Thomas
Chief, Highway Maintenance

From : DEPARTMENT OF TRANSPORTATION
Transportation Laboratory

Subject: Edge Drains

In establishing priorities for installation of edge drains for concrete pavements, it is necessary to first separate them into two basic categories: (1) those with ride scores less than 45 and (2) those with ride scores greater than 45. This procedure will serve to differentiate the "triggered" vs "untriggered" pavements as determined by the PMS.

In category 1 it is our feeling that the greatest benefit can be achieved by installing drains on the newest pavements. Thus, age of pavement can be used directly in establishing priority. A physical measurement or parameter that could also be used wou[illegible] be the actual average step-off as determined by a faulting gage. Lowest faulting would give the highest priority. About 25 to [illegible] consecutive joints have to be measured to arrive at a reproduc[illegible] number for a given location. These are several problems associ[illegible] with this approach. These include: (1) cost of making such a survey, (2) hazard to individuals making survey and to the tra[illegible] public, and (3) an understanding that, while pavement faulting the major concern, some general deterioration of base may be without an immediate contribution to faulting. Since faulti[illegible] increases with time, but at rates that vary from project to [illegible] simply using age is preferable in establishing priorities.

Factors that could be considered as modifiers to priorities established might be:

1. Traffic - High truck volumes to receive higher prio[illegible]
2. Location - Coastal and mountain regions to receive [illegible] priority than valley and semi-arid regions. The [illegible] number of rainfall days or inches of annual rainfal[illegible] be used as a parameter.
3. Local conditions - There may be areas where local [illegible] such as performance record, traffic conditions, l[illegible] drainage conditions, etc. will be major considera[illegible] decision to install edge drains.

In category 2 (ride score greater than 45) the projects will have been triggered for some type of rehabilitation. In these cases each project will need to be examined to determine the appropriate strategy and whether deterioration is too advanced to warrent an edge drain installation.

To summarize, the following are believed to be the primary factors in prioritizing edge drain installations for category 1 pavements in descending order of importance:

1. Pavement age
2. Rainfall
3. Traffic

The following is a prioritizing scheme which would weight these factors in approximate terms of their relative importance:

Age	Factor
1 - 5 yrs.	2
5 - 10 yrs.	4
10 - 15 yrs.	6
15+	8
Annual Rainfall (inches)	
<10	1.5
10 - 20	1.2
20 - 40	0.8
40 - 60	0.6
60+	0.5
Traffic (TI)	
<12	1.0
>12	0.8

E. B. Thomas
Page 3
March 2, 1982

Multiplication of these 3 factors for a given pavement in category 1 (ride score <45) will result in a priority number, the lowest number representing the highest priority.

This approach has been tested on several pavements as shown below:

Project	Age	X	Rainfall	X	Traffic	=	Priority
I-10 (Cabezon)	6		1.5		1.0	=	9.0
I-10 (Colton)	8		1.2		0.8	=	7.7
99 (Delhi)	2		1.2		1.0	=	2.4
I-5 (Mt. Shasta)	8		0.5		1.0	=	4.0
I-15 (Elsinore)	2		1.5		0.8	=	2.4
101 (SLO)	8		1.2		1.0	=	9.6

The relative values appear reasonable in terms of the present condition of the subject pavement. It should be emphasized that the suggested priority number would represent a preliminary value which would be subject to modification based upon local conditions.

G. L. RUSSELL
Chief, Transportation Laboratory

JHW/RAF:dka