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16. ABSTRACT

The increasing attractiveness of emulsified asphalt from ecological and energy conservation viewpoints precipitated this study of the performance of dense-graded and open-graded asphalt concrete surface courses containing emulsified asphalt. A total of two (each) test sections containing dense-graded and open graded cold mix were constructed and their performance monitored for one to five years. In addition, several cold-mix pavements placed in Oregon and Washington were viewed and some laboratory mix design work completed toward the development of an improved mix design procedure for cold-mixed dense-graded asphalt concrete. It was concluded that the field curing problems associated with dense-graded cold-mix AC surfacing would preclude their use for most Caltrans paving and that the use of cold-mix open-graded AC offers the possibility of being a viable alternative to hot mix, particularly in remote locations. The construction of additional cold-mix open-graded test sections is recommended.

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DIVISION OF CONSTRUCTION
TRANSPORTATION LABORATORY
RESEARCH REPORT

COLD-MIX ASPHALT CONCRETE SURFACING

FINAL REPORT

FHWA-CA-TL-3542-77-23

AUG. 1977

Prepared in Cooperation with the U.S. Department of Transportation,
Federal Highway Administration

Caltrans
CALIFORNIA DEPARTMENT OF TRANSPORTATION

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

August 1977

FHWA No. G-2-8
TL No. 653542

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

COLD-MIX ASPHALT CONCRETE SURFACING

Study made by . . . . . Roadbed & Concrete Branch

Under the Supervision of . . . . . Donald L. Spellman, P.E.

Principal Investigator . . . . . Robert N. Doty, P.E.

Co-Principal Investigator . . . . . Thomas Scrimsher, P.E.

Report Prepared by . . . . . Thomas Scrimsher and Robert N. Doty

Very truly yours,

George A Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

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This work was performed as a research project conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration, under item No. G-2-8. The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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I. INTRODUCTION

An obvious, often unsightly contributor to air pollution has been the manufacturing of hot asphalt concrete mixtures. Contaminants are discharged into the air from the burning of fuels used for heating and drying aggregate, from dust produced during subsequent handling of the dry aggregate prior to mixing with asphalt, from the mixing operation, and from the completed mixture during subsequent paving operations. Therefore, the California Department of Transportation initiated a project to determine, by field trials and evaluation, if cold mix asphalt concrete could be used to reduce pollution and, at the same time, provide a durable asphalt concrete pavement. In conjunction with this field work, laboratory work on the design of asphalt concrete mixtures containing emulsified asphalt was also accomplished.

The first field project studied was a one mile test section consisting of an .08-foot (24.4 mm) thick cold mix asphalt concrete overlay. This section is located on Highway 30 near the city of Fontana, California. It was constructed in September, 1971 and an interim report on this project was published in December 1972 (1). The second field project studied was a city street located in the city of Pacifica, California. It consisted of placing an open graded cold mix approximately .08 foot (24.4 mm) thick for approximately 0.1 mile (158.5 m).

The third field project was located on State Route 1 in the city of El Segundo, California. It consisted of placing a 0.25 foot-thick (76.2 mm) dense-graded cold mix 25 feet (7.62 m) wide for 0.5 mile (804.7 m). This pavement was constructed as a leveling course and subsequently overlaid with a 0.2 foot (61.0 mm) layer of conventional hot asphalt

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concrete. However, due to stage construction, it also served as a wearing surface for traffic for a period of approximately 40 days.

During the field studies, laboratory studies with various emulsions, aggregate gradations, and methods of compaction were also undertaken in an attempt to provide an improved method of laboratory mix design. Although this goal was not achieved completely, some valuable data and a better understanding of emulsion mixtures was obtained.

II. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been developed based upon the performance of the four California test sections studied, the pavements observed in the Pacific Northwest, and the laboratory mix design and testing work described.

1. Open-graded cold-mix asphalt concrete surfacing has the potential of providing adequate in-service performance if proper emulsion formulations can be developed. It should be considered a potentially viable alternative to hot mix, particularly in remote locations.

2. The need for a choker* when constructing the open-graded cold-mix pavement will result in a surface with an appearance approaching that of a dense graded surface, at least in some cases. Thus, the amount of choker used should be the minimum required to prevent pickup.

*"Choker", as used in this report, is a term used to describe the sand placed upon the completed surface of an Open Graded Emulsion Mix to temporarily seal or "choke" off the surface voids. This is done to allow the placement of a chip seal without excess drainage of the chip seal binder. It also serves to prevent "pickup" from rubber tires if pneumatic compaction is used or when traffic is permitted during the early curing period.

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3. Aggregate gradations coarser than the 3/8 (9.5 mm) x No. 6 gradation used to date by Caltrans for open-graded cold-mix should be tried in an attempt to obtain the satisfactory performance of coarser mixes as reported from the Pacific Northwest.

4. The relatively slow cure associated with dense-graded cold-mix asphalt concrete surfacing is a major problem. It will significantly limit the number of potential uses of this paving material due to the apparent need for very thin (0.08 foot [24.4 mm]) lifts, or a long delay before permitting the road to be opened to traffic.

5. Cold-mixes may be very sensitive to the length of the mixing cycle used in batch plants. Thus, the use of continuous mix plants should be encouraged.

6. There is the likelihood that substantial hardening of the base asphalt occurs during the manufacture of the emulsion and/or the construction operation.

7. Dense-graded cold mixes will have cured-out void contents considerably greater than their hot-mix counterparts, thus suggesting the use of construction seals to counteract, at least partially, the probable accelerated rate of hardening of the binder due to this open structure.

8. The use of the cold mix operation will result in a decrease in hydrocarbon emissions and may result in a decrease in particulate emissions, depending upon the moisture content of the aggregate at the time it is being processed at the plant.

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9. The use of cold-mix in lieu of hot-mix may or may not result in a cost saving. The decrease in plant cost and high production potential of the commonly used continuous portable plants is counteracted, at least somewhat, by the cost of emulsified asphalt. Emulsified asphalt, although containing approximately 40 percent water, often costs as much as or more than paving grade asphalt.

III. IMPLEMENTATION

The construction of test sections containing open-graded cold mix asphalt concrete surfacing will be encouraged. The mix design procedure for dense-graded cold mix asphalt concrete developed as part of this study will be tried if conditions warranting this type of construction occur. Test Method No. Calif. 310 will be modified in accordance with the findings contained herein for measuring the asphalt content of asphalt concrete manufactured using emulsified asphalt.

IV. DISCUSSION

A. General

Due to the present and possible increased fuel and energy shortage, the expanded use of emulsified asphalt must be considered when planning for future roadway construction. From an environmental standpoint alone, cold mixtures containing emulsified asphalt offer potential advantages in these areas compared to hot asphaltic mixtures. In addition, cold mixes also offer potential advantages from a cost standpoint due to the relative simplicity of the plant equipment required compared to that required for a hot mix. However, as of 1971

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very little work had been completed documenting the performance of emulsion mixes as surfacing for fairly heavily traveled roadways. Also, a general lack of proven mix design procedures and field control tests was noted as well as some confusion regarding the desirability of permitting uncoated aggregate (gray backs). Thus, the primary purpose of this study was to evaluate the performance of emulsion mixtures as roadway surfacing. Associated with this was the need to study and evaluate the mechanics of emulsion mixtures with regard to laboratory mix design and construction problems such as mixing, placing and curing.

B. Project No. 1 - Fontana

Project Description

This test section consisted of one mile of 1-inch (25.4 mm) thick cold mix overlay on Route 30 near Fontana, California. This highway is a 2-lane asphalt concrete facility used by approximately 4000 vehicles per day, 17 percent of which are trucks. Traffic on the highway often travels 50 to 65 miles per hour (80 to 104 Kms/hr) at the location of the test section.

This area has an average rainfall of about 15 inches (0.38 m) per year. Ambient temperatures range from about 115°F (46°C) in the summer to a low of 25°F (4°C) during the winter. Most of the project was shaded by tall Eucalyptus trees located within 20 feet (6.10 m) of the south edge of the roadway. Drainage ditches are located along both sides of the roadway and the adjacent farmland consists of abandoned citrus orchards and uncultivated fields.

At the time this location was selected, a resurfacing contract was underway that consisted of placing a 0.08-foot (24.4 mm)

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thick hot mix dense graded asphalt concrete on the existing pavement. Several years prior to this resurfacing, Route 30 had been widened 2 feet (.60 m) on each side to provide additional shoulder area. These areas were cracked and slightly depressed from the traveled way, resulting in a rather rough riding section near the edge. The major portion of the traveled way had only occasional cracking and was in fairly good condition. Therefore, the new construction called for resurfacing the entire width including the 2 foot (.60 m) shoulders.

The aggregate used for this job was an all-crushed streambed gravel of good, sound quality. The gradings selected for use were: (1) a dense grading conforming to the tolerances for California's 1/2-inch (12.7 mm) medium grading and (2) an open grading conforming to the tolerances for 3/8 (9.5 mm) x #6 seal coat screenings (2). The sand used as a choker for the open graded mixture was obtained from the No. 1 bin (-#8 fraction) at the plant.

CMS-2h and CSS-1h emulsions (Section 94, Calif. Standard Spec's) were supplied by the Chevron Asphalt Company. The CMS-2h was used for the open-graded mix in the amounts of 6, 6 1/2, and 7 percent by dry weight of the aggregate. The CSS-1h was used for the dense graded mix in the amounts of 8 and 8 1/2 percent. A conventional 3000 lb. (1361 Kg) Madsen batch plant was used "cold" to mix both the dense-graded and the open-graded asphalt concrete (Figure 1). The mix was placed in three 10-foot (3.05 m) widths with a Barber-Greene paver and compacted using various combinations of a 12-ton (10.89 metric tons) tandem steel roller and a 10-ton (9.08 metric tons) pneumatic roller (34 psi [234.4 kPa] tire pressure). The ambient temperature during the paving operation varied from 70°F (21°C) to 90°F (32°C). These construction operations are described and illustrated in detail in Reference 1.

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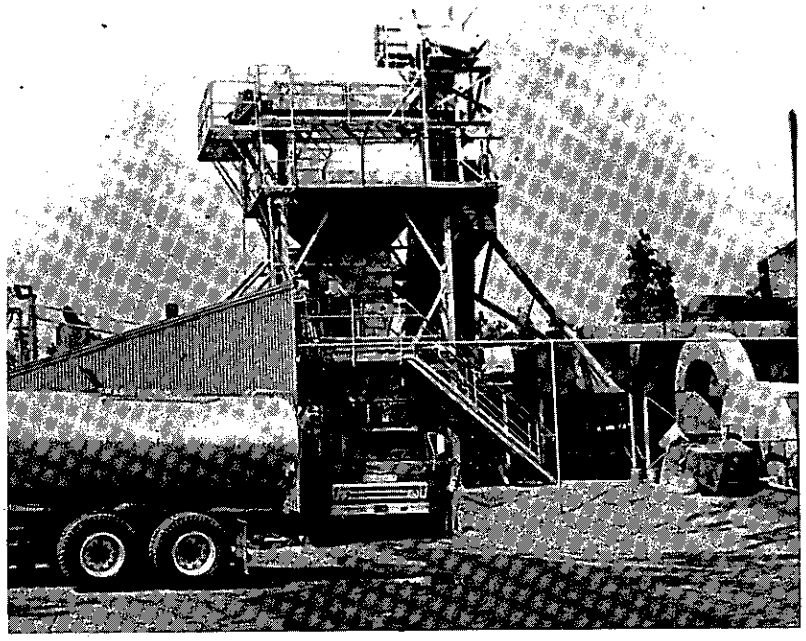

Figure 1

Pavement Performance

Open-graded Mix - The open graded mix had noticeable surface raveling with two or three areas raveled through to the overlaid surface after less than 24 hours of traffic. It was felt that the severe raveling was due, at least in part, to placing the sand choker too early. This appeared to have retarded the curing and resulted in a lack of surface cohesion. The raveling was generally confined to the wheel track areas.

After 90 days, the open graded mixture had not deteriorated greatly from the initial observations. It was evident, however, that a few aggregate particles were still being displaced. Hairline cracks were visible when the pavement was wet and were attributed to reflective cracking. The edges of the open graded mix were friable and easily displaced. Also, two or three areas which had severely raveled immediately after construction had been patched.

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The sections of open graded mix containing the various emulsion contents could not be differentiated visually during the 90-day or any subsequent condition survey. The riding quality of all the open graded mix was considered inferior to that of the adjacent hot mix overlay.

The next field review occurred approximately six months after construction and revealed that the open graded mix had deteriorated further. The severity of the previously observed hairline reflective cracking had increased and some cracks were spalling. There was some additional raveling through to the overlaid surface and raveling along the edge of pavement.

The worst areas of raveling were in the westbound lane at the beginning of the open graded overlay where the heaviest application of choker sand was used. Also, raveling was generally greater in the westbound than in the eastbound lane. Observations of truck traffic indicate that the majority of the trucks traveling westbound were loaded while those traveling eastbound often were not loaded. This appeared to be a result of the local commerce and may have been the reason for the increased raveling in the westbound lane. The portion of the open graded mix immediately adjacent to the cold mix dense graded section was in good condition. Tracking of the fog seal from the dense graded surface to the open graded surface is a possible explanation for this better performance.

A field survey during the twelfth month of service life revealed that raveling of the open graded mix had somewhat stabilized. There again were areas of complete raveling extending through the experimental surface but the overall condition was about the same as that observed previously. However, longitudinal construction joints were visible in certain locations.

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The condition of this open-graded surface continued to deteriorate gradually. As of 1975, the surface had cracked enough to require the application of a chip seal to prevent further deterioration.

Dense-graded Mix (Fontana) - The dense graded mixture also raveled slightly during the initial 24-hour period. In addition, a brown color was evident along the outer 2 feet (.60 m) of the pavement after 24 hours, thus indicating that the CSS-1h emulsion had not cured completely. Unfortunately, the application of a fog seal to the pavement resulted in serious tearing and raveling of the surface when the emulsion began to break, while exposed to traffic. Further damage was prevented by sanding the surface.

The 90-day pavement survey indicated that the dense mix in the area where a fog seal had not been applied had substantial surface raveling. The dense graded mix with a fog seal also had experienced some additional surface raveling. A small amount of hairline cracking was also noted. Edges of the mix were friable and easily displaced with foot pressure as in the case of the open graded mix. Also, some loss of material from the edge of the lanes was noted.

The six month field review revealed that the dense graded mixture which had been sealed appeared essentially the same as it did after 90 days. The hairline cracking observed previously appeared to have healed and the surface raveling had not progressed. The dense graded mixture that was not sealed still showed signs of progressive raveling. However, this raveling and some isolated aggregate pop-outs were not severe enough to warrant corrective treatment at that time.

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An inspection was made during the twelfth month of service and the sealed dense graded surface had generally improved in appearance. Traffic seemed to have smoothed out the effects of the raveling caused by the original fog seal though some signs of abrasion still were evident and in some areas the longitudinal construction joint was obvious. The unsealed area had continued to deteriorate and was definitely in need of a maintenance seal. Crescent shaped slippage cracks caused by the heavy truck traffic shortly after paving were still present and in one case the material had raveled through to the overlaid pavement in an area approximately 6 inches (152.4 mm) in diameter.

The riding quality of the dense graded cold mix surface was not considered to be as good as the adjacent sections of hot mix overlay but about equal to that provided by the open-graded cold mix surface. The adjacent hot mix surfacing appeared to be in excellent condition without any indication of distress except for a very minor amount of reflective cracking noticeable during the twelve-month inspection. In 1974, most of the dense-graded cold mix pavement was destroyed as part of the construction of an interchange with Interstate 15.

Skid resistance measurements were obtained with a towed trailer skid tester operated in conformance with ASTM Test Method E-274. The results were as follows:

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Table 1

Average Skid Number at 40 MPH (SN_{40})
Fontana Test Section

	11/71	8/72	5/74
Dense Graded Mix			
(1) No Fog Seal	49	49	51
(2) One Fog Seal	49	52	50
(3) Two Fog Seals	33	40	45
Open Graded Mix	56	53	50
Adjacent Dense Graded Hot Mix	--	50	55

It can be seen that the dense graded mix without a fog seal and with one fog seal provided good skid resistance (Table 1); however, these surfaces were badly raveled at the time of testing (Figure 2). This raveling was not acceptable, thus requiring a second fog seal which reduced the skid resistance measurably. The skid resistance of the dense graded mix with two fog seals did increase to a satisfactory level within the first year. It can also be seen that the adjacent dense graded hot mix had good skid resistance.

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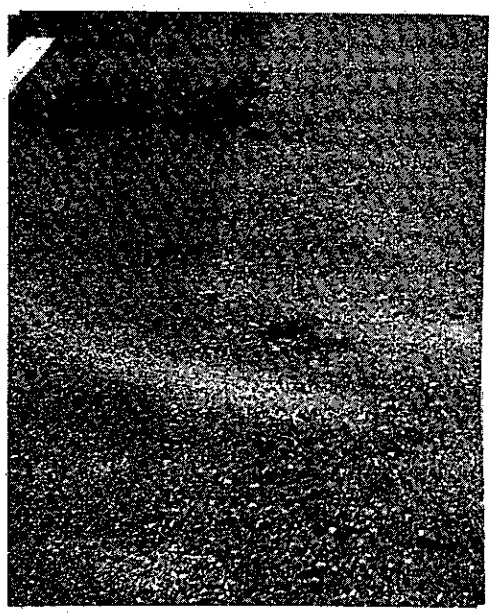
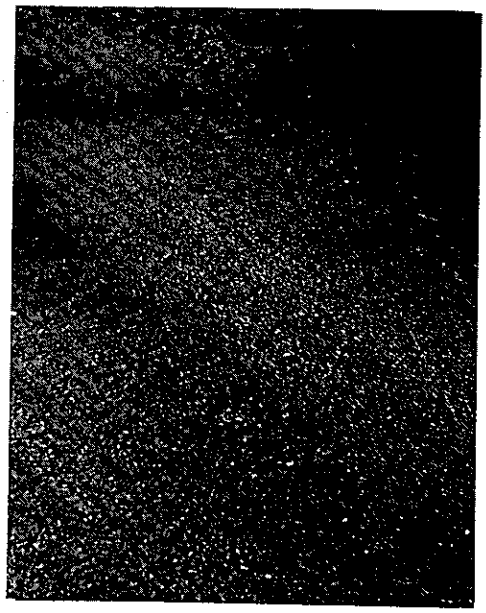


Raveling in Dense
Graded Surface
No Fog Seal



Raveling in Dense
Graded Surface
With Fog Seal

Figure 2

The open graded mix not only had good skid resistance but also provided excellent surface drainage characteristics. This is illustrated in Figure 3 which shows a comparison between the open graded surface and the abutting hot mix dense graded surface during a rainstorm. It is evident that the open graded mix has good potential as a skid resistant treatment with excellent drainage characteristics.

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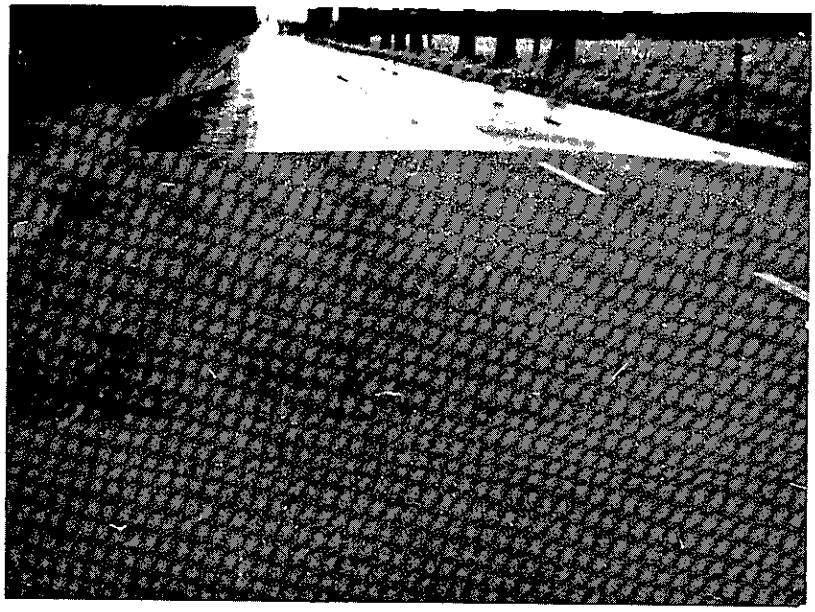

Grading Contrast in the Rain
Figure 3

C. Project No. 2 - Pacifica

Project Description

This experimental project consisted of an attempt to construct a 0.08-foot (24.4 mm) thick cold mixed OGAC on State Route 1 adjacent to the city of Pacifica, California. This 4-lane roadway is a heavily travelled route (Traffic Index = 9.5 - see ref. 3) located within 1 mile of the Pacific Ocean. The length of the project was 2.4 miles (3.86 Km). The ambient temperature during the attempted construction of this pavement varied from 50°F (10°C) to 70°F (21.1°C).

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Materials

The aggregate was from a supply just south of the city of Pacifica and was predominantly a limestone. The 3/8" (9.5 mm) x No. 6 gradation tried at Fontana was again specified for this job. Although anionic emulsions are generally selected for use with limestone aggregates, a CMS-2 was recommended for this project by the Asphalt Division of Chevron USA Inc. The selection was an attempt to minimize the time required for the emulsion to break after placing the mix because of the cool, moist weather predominant in Pacifica. The emulsion was supplied (by Chevron) out of Oakland. Prior to construction, mineral aggregate samples from this pit at the Pacifica quarry were sent to the Caltrans laboratory in Sacramento and also to the laboratory of Chevron USA Inc. in Emeryville for testing with CMS-2 emulsion. No problems were encountered at either laboratory when mixing the CMS-2 with the project aggregate so 9.0% emulsion (by dry weight of the aggregate) was recommended.

Plant Operations

A continuous mixing plant previously used for cement treated base production was converted by the Contractor for producing the cold mix (Figure 4).

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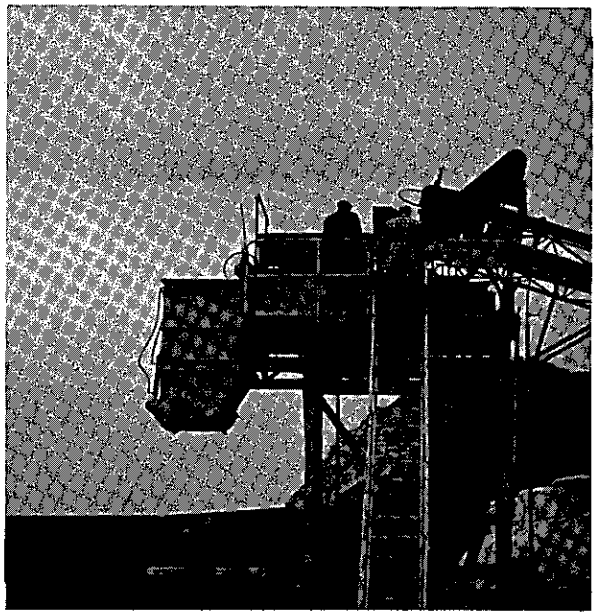

Converted CTB Plant
Figure 4

Approximately one week before the Contractor planned to start paving operations, test runs of the modified CTB mixing plant using the specified CMS-2 asphalt emulsion and the proposed aggregates were begun. The first test runs all failed to provide the desired (essentially 100%) coating of the aggregate with the emulsion. Several plant modifications were made such as the addition of facilities to moisten the aggregate, movement of the spray bar in the pug mill, etc., followed by additional trial runs but no significant improvement in aggregate coating was obtained.

Attention was then shifted to the CMS-2 asphalt emulsion that had been delivered to the project. This approach was suggested by technical personnel from Chevron USA Inc. Chevron technicians added various percentages of solvent and various amounts of emulsifier to the CMS-2 which was in the storage tank on the job. This was followed by the preparation of additional trial batches. Minor improvements were

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noted in some cases but the coating of the aggregate was still not satisfactory. With the addition of more solvents, other negative features in the mixtures started to appear such as excessive bleeding of the mixture and slower setting time.

Although field additions of oil distillate were not satisfactory, a significant difference was noted in the laboratory when emulsions with varying amounts of oil distillate were used. The CMS-2 emulsion containing 6.0% oil distillate delivered to the job failed the AASHTO-T 59 test for coating ability and water resistance whereas the CMS-2 containing 9.3% oil distillate that had been supplied for the preliminary testing did pass this test. Both these emulsions complied with the permissible 12% maximum oil distillate permitted by the job specifications.

Chevron personnel were confident at this point that by making some minor changes in the blending of the asphalt emulsion at the refinery, they could overcome the aggregate coating problem. Everyone was in agreement with Chevron's proposal including the prime contractor. The old CMS-2 asphalt emulsion in the storage tank was pumped out and a new shipment of CMS-2 emulsion delivered. However, trial runs using this emulsion again resulted in a poorly coated mixture (more then 50% uncoated particles). Although Chevron personnel continued their testing using various formulations of cationic and anionic emulsion, the State DOT personnel decided that because of the lack of progress to date, no further delays would be permitted so a change order was issued to use regular open graded hot mix for the Highway 1 job.

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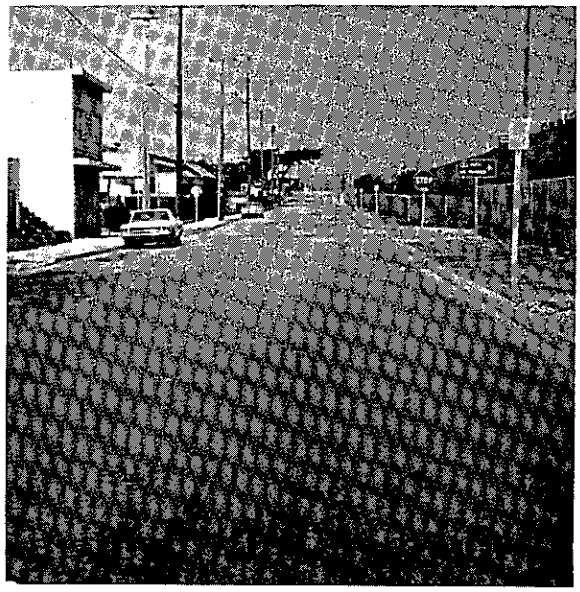
The Chevron Asphalt Company then approached the City of Pacifica regarding the use of a cold-mix for some of the paving then underway on the city streets. A city street adjacent to State Route 1 was subsequently selected for a test. This test section was located on Francisco Boulevard, a two-lane roadway with parking along one side (Figure 5). The test section was approximately 32 feet (9.75 m) wide and 400 feet (121.92 m) long. Some of the 3/8" (9.5 mm) x No. 6 aggregate stockpiled for the State Contract was used for the City job as well as the plant that was modified for the State work. An anionic MS-2 emulsion having the properties shown in Table 2 was used for this work.



Francisco Blvd.
Figure 5

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Table 2

Emulsion Test Results
(MS-2)

Pacifica Test Section

Test	Test Result	AASHTO T-59 Specifications
Viscosity SSF @ 77°F (25°C), sec	500+	100 Min.
Residue by distillation, percent	68.3	65 Min.
Penetration of residue from distillation, 77°F (25°C)	98	100 to 200
Sieve test, percent	0	0.10 Max.
Coating ability and water resistance		
Coating, dry aggregate	Good	Good
Coating, after spraying	Poor	Fair
Oil distillate by vol. of emulsion, percent	7.5	No Requirement

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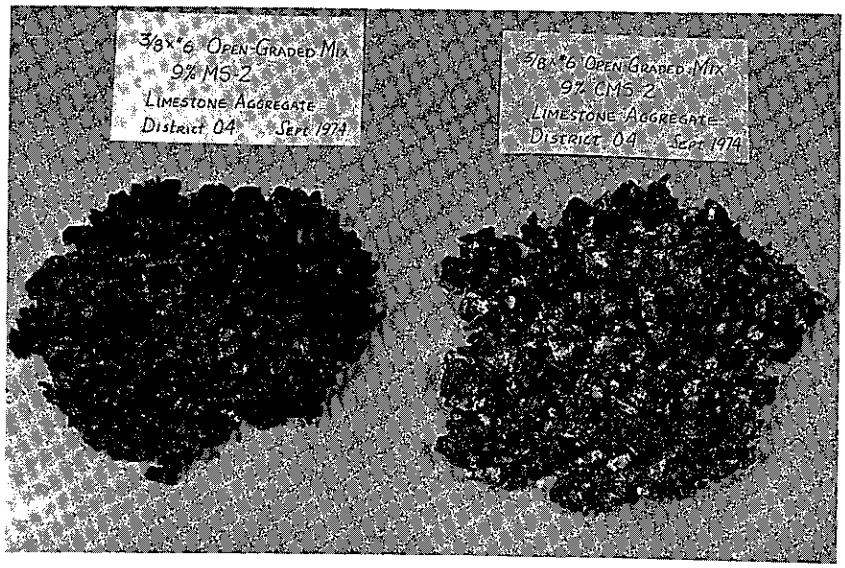
A rain earlier in the week left the aggregate stockpile wet. Per the Speedy Moisture Tester, the moisture content of the stockpile was determined to be about 1.9% so no additional water was added to the aggregate and no drying of the aggregate was attempted.

Emulsion was supplied by Chevron in Oakland and was delivered at a temperature of 95°F (35°C). The plant was set to run 5,250 lbs (2381 Kgs) of aggregate per minute and a quantity of emulsion equal to 9.0% (by dry weight of the aggregate) was used. The spray bar for the emulsion was located midway in the pug (about 3 feet (.91 m) from discharge). The emulsion was pumped to the plant directly from the truck. It appeared to pump easier than the CMS-2 previously used for the aborted State project. Also, in contrast to the CMS-2, the MS-2 emulsion coated the aggregate very well (Figure 6).



Emulsion Mixing Comparison
Figure 6

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Paving Operation

The street was barricaded to traffic, swept clean, and paved. No tack coat was used. The air temperature was 61°F (16°C) with a clear sky. Paving was started at 9:45 a.m. and was completed by 10:45 a.m. The mix looked excellent. It appeared well-coated and brown with no evidence of uncoated particles. A Blaw-Knox paver with tracks was used and two lane widths of 12 feet (3.66 m) each and one of 8 feet (2.44 m) were placed (Figure 7). Paving started at Claridon Street for each lane and continued south to Lakeside Avenue. A thickness of approximately 0.08 feet (24.4 mm) was placed. Some dragging of aggregate in spots required considerable raking until the paver was finally adjusted properly. No rolling was attempted until all the paving was completed.

The mix began to turn black 15 to 20 minutes after placing. A 12-ton (10.89 metric tons) tandem roller was used for breakdown with water-detergent mixture used to keep the wheels clean. The roller was used directly on the mix without any choker sand and one complete coverage was applied.

There was no "pickup". Immediately after breakdown rolling, a sand truck was backed down the center and two men walking behind the truck spread the sand using shovels (Figure 8). A light coverage was applied. After sanding, a 10 ton (9.08 metric tons) pneumatic roller was used to apply one coverage. The steel wheel tandem was tried again but it appeared to cause excessive movement under the wheel (waves) so it was decided to use only the pneumatic after breakdown. Compaction with the pneumatic roller appeared excellent. No water was used on the wheels of the pneumatic and, because of the sanding, no pickup on the wheels was noticed.

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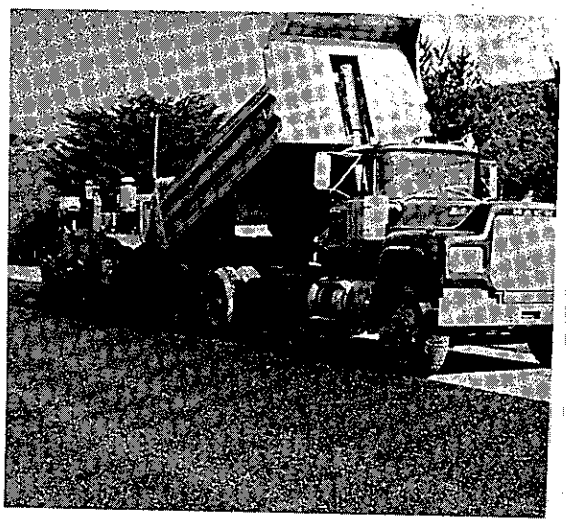
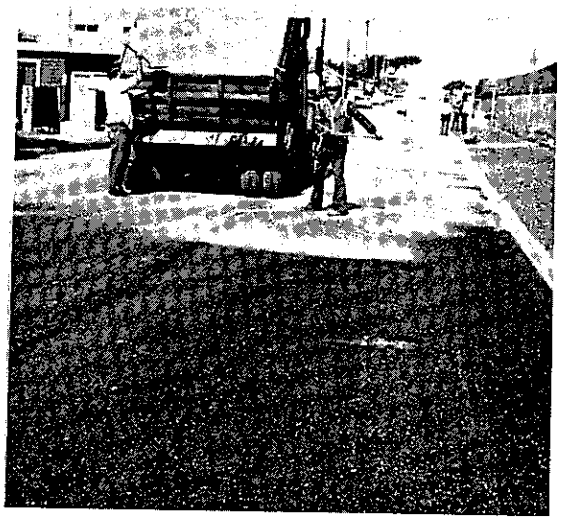
It was observed that after final rolling but before opening the roadway to traffic, several "fat" spots began to appear (Figure 9). However, only one small spot actually resulted in run-off into the gutter. All the "fat" spots were sanded a second time before allowing traffic to use the street. All rolling was completed at 12:30 p.m. and traffic was permitted on the street at 1:00 p.m. After one hour of traffic, no visible distress was evident except for one "fat" spot which once again began to bleed through the sand. It was located in the southbound lane 4 feet (1.22 m) from the curb.



Paving
Figure 7



Sanding
Figure 8

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Fat Spots
Figure 9

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Air Pollution

No actual measurements of plant emissions or emissions from the mix were accomplished on this city job. However, no visible emissions were noted during any portion of the mixing or paving operations. In addition, no strong odor was noted that could be associated with the evaporation of any cutter stock from the emulsion.

Pavement Performance

There was very little distress noted on this job during the first 24 hours after opening it to traffic. The distress that did occur was near the curb line and was the result of parking maneuvers. There was also some distress within 24 hours noted where turning motions were causing a slight surface tearing at an intersection. However, the general traveled way through the project carried traffic well during the first 24 hours without any evidence of serious ravelling or tearing.

After one week, the job looked good with only minimum distress from ravelling or tearing. The worst area was located at the intersection with Claridon Street. It did not appear to be progressing, however. A few bleeding areas were noted in the northbound lane about midway in the project, although they were not extensive. Some scuffing and tearing were noted in the parking area to the extent that holes had developed completely through the overlay (Figure 10). Evidence of runoff in the gutter was negligible with only a couple of gutter stains apparent.

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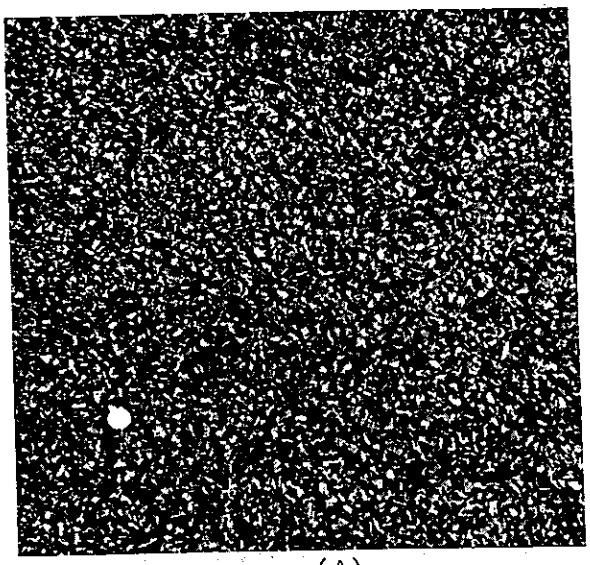
After One Week of Traffic

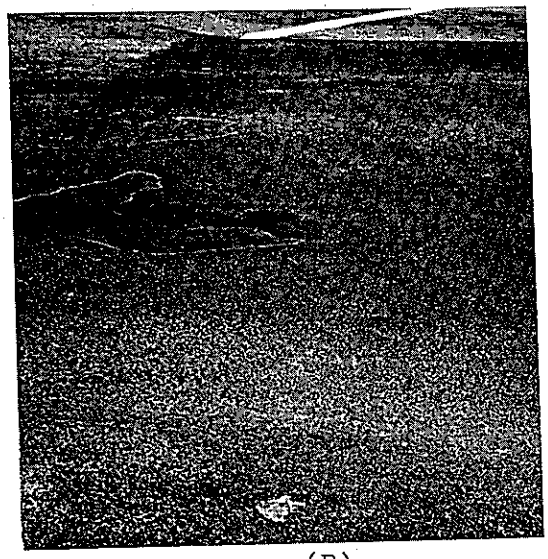


(A)

General Texture

(C)

Parking Area



(B)

Intersection at Claridon

(D)

General View
(Hole has sand blotted fat spots)

Figure 10

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The emulsion appeared to be "broken" and the mix well-set. The travelled area appeared denser than the nontravelled areas near the curb line. Only a trace of the choker sand was apparent.

Ten days after construction, heavy rains occurred. Emulsion was observed being washed from the mix into the gutter area. The drainage, in general, accumulated in the city storm drains; however, near Lakeside Avenue some pavement flooding occurred. The runoff in a drainage ditch located adjacent to a golf course had the distinct brown appearance of unbroken emulsion. No damage was exhibited by the pavement, however.

An inspection after 20 days from placement revealed the pavement to be visually in the same condition as that noted after the first week.

After one year of use, the section of Francisco Boulevard that was overlaid with cold mix appeared about the same as it did the day it was placed. The early distress attributed to tearing of the mat from turning motions on Claridon Street had not progressed. The roadway itself (the traveled way) was in good condition. The texture had a porous, open look to it. The mix did not appear to have any "fat" spots evident other than a slight tinge recognizable from the earlier notations of the "fat" spots. These had not become a problem of any kind. There was no rutting or raveling evident and the mix looked good.

The visual condition of the pavement after two years was about the same. The surface texture still was very open although slightly more dense appearing than the original mix. There was no evidence of ravelling, rutting, bleeding, or distress other than that caused by turning movements within the first 24 hours after placement.

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Skid resistance measurements were taken in 1974 and again in 1976. The results of this testing are shown in Table 3, below.

Table 3

Pavement Skid Resistance
Pacifica Test Section

Date	Pavement Skid No. (SN_{40} per ASTM E-274)	Remarks
11-5-74	36 39 39	All values converted from test results per Test Method No. Calif. 342-D per Ref. 4.
11-3-76	33 39 41 41	All values converted from the results of tests conducted at 25 or 35 mph (40 or 56 Kms/hr).

The skid resistance of this surfacing is slightly less than that typical of an open graded asphalt concrete, particularly the first test in 1976. There may have been some localized densification from aggregate segregation combined with compaction by traffic that resulted in the lower test value. However, this was not visually evident. All of the values are generally satisfactory for vehicle speeds below 40 mph (64.4 Km/Hr) and all but one are satisfactory for highway speeds.

D. Project No. 3 - El Segundo

Project Description

This test section was located in the two northbound lanes of State Route 1 in the immediate vicinity of the Los Angeles International Airport. The roadway is located in the city of El Segundo and is designated as Sepulveda Boulevard. The

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traffic in this area is fairly heavy with a Traffic Index (3) of 8.0. The climate in this area is mild with daytime ambient temperatures of 75-80°F (24°-27°C) for much of the year.

The exact location of the test section was on Sepulveda Blvd. between El Segundo Blvd. and Mariposa Blvd. The job was 0.5 miles (.80 Km) long. The cold mix portion consisted of a 0.25-foot (76.2 mm) thick leveling course on Class 2 Aggregate Base (2). Due to traffic handling problems, this leveling course was used to carry traffic for a period of 30-40 days prior to the construction of the 0.25-foot (76.2 mm) thick surface course. Cold DGAC was used in lieu of the hot DGAC originally planned for the leveling course to study the performance of a cold mix product developed by the Douglas Oil Company.

Materials

The aggregate used for the cold dense-graded mix complied with the specifications for the 3/4-inch (19.05 mm) max medium grading in the Caltrans Standard Specifications (2). The emulsion used for this paving was designated as Docal 1054 and produced by the Douglas Oil Company. In addition a small amount (0.25% by weight of the aggregate) of Type II portland cement was added to the mix to accelerate the rate of curing of the mix.

The properties of the aggregate, emulsion, and cold mix for this test section were as shown in Table 4, below:

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Table 4

EMULSION (Docal 1054)	Sample No. 761-48	761-50
Saybolt Furol Viscosity, 77°F (25°C), sec.	20	17
Percent distillate by volume of emulsion	60.5	58.3
Penetration on distillation residue, 77°F (25°C)	58	55

AGGREGATE

Gradation
Percent Passing

Test No. 76-1017	3/4" (19.1mm)	1/2" (12.7mm)	3/8" (9.5mm)	No. 4	8	16	30	50	100	200
	100	82	74	55	37	28	20	12	7	5

Specific Gravity		K-Value		Surface Area
Coarse	2.67	Coarse	1.1	25.42 Ft^2/lb
Fine	2.69	Fine	1.1	(2.36 m^2)/.4536 Kgs

COLD MIX ASPHALT CONCRETE

Binder Grade	Binder Amount	Compact Method	Relative Compact.	Stability[1] @ 140°F (60°C)	Specif. Gravity	Percent Voids	Surf. Abrasion[2] Loss
AR-4000	5.2%	Kneading	100%	40	2.37	4.0%	0.2 gm
Docal 1054	8.5%	Static	96%	30*	2.28	6.0%	1.7 gm

*Tested after 7-day cure at room temperature of 77°F± (25°C).

[1]Per Test Method No. Calif. 366

[2]Per Test Method No. Calif. 360, Method A.

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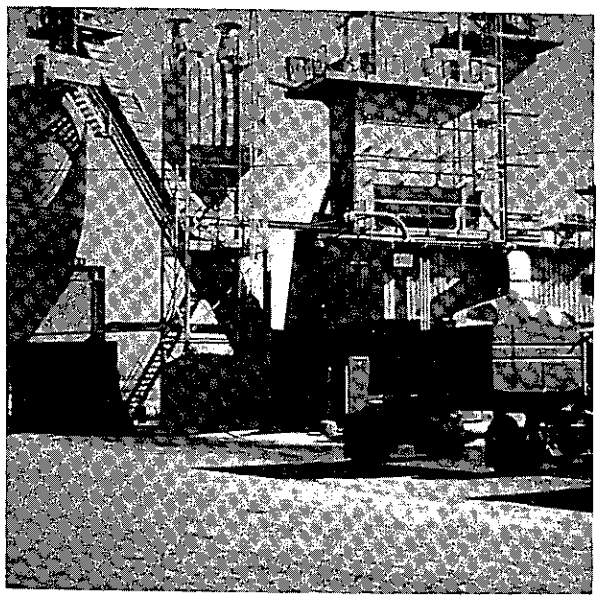
Plant Operations

The plant was a "Standard" batch plant owned by the Vernon Paving Company (Figure 11). It was modified slightly for the "cold" mixes. One modification consisted of the addition of a bypass chute at the top of the hot elevator so the aggregate would be deposited directly in the No. 1 bin without passing thru the hot screen. Another modification consisted of the addition of a water line with a meter for adding water and a third modification consisted of batching entirely on a cold feed basis. The plant was located at Irwindale, approximately 55 miles (88.50 Km) from the job. The average travel time was one hour and fifteen minutes.



Plant Photo
Figure 11

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A total of 17 trucks was used. Each truck and trailer carried about 24 tons (21.78 metric tons of mix). No water, Diesel oil, or other "release" agent was used. The operation consisted of batching by cold feed onto a conveyor belt, transporting the combined aggregate through the unheated dryer, up the hot elevator, and thru the bypass chute into the No. 1 bin. From this bin a 3 ton (2.72 metric ton) batch (later increased to a 4 ton [3.63 metric ton] batch) was weighed and a total of 1.0% moisture was added. The aggregate already had 4.5% moisture so the total pre-mix moisture was 5.5%. The 8.5% emulsion content used was that required to provide the amount of residual asphalt required for a hot mix design for this aggregate. A quantity of Type II portland cement equivalent to 0.25% by weight of the aggregate was also added prior to mixing.

The actual batching was a two-man operation. One man batched the water while another batched all the other ingredients. The 25-second "dry" mix cycle consisted of mixing the aggregate, water and portland cement. This was followed by the addition of the emulsion and a 20-second "wet" mixing cycle.

Some of the problems observed included delays caused by an apparent overload of the cold feed belt, aggregate overflow from the No. 1 bin into the No. 2 bin, and aggregate segregation caused by excessive manipulation of the cold feed. In addition, the plant Foreman indicated that replacement of the pugmill liner and/or the pugmill shank and paddles would probably be required due to the abrasive characteristics of the cold mix during the "dry" premix cycle. The emulsion was pumped directly from the delivery trucks to the asphalt weigh bucket (a container which limited the batch size to 4 tons [3.62 metric tons] due to its capacity). The mix coming from the pugmill looked brown and all of the aggregate

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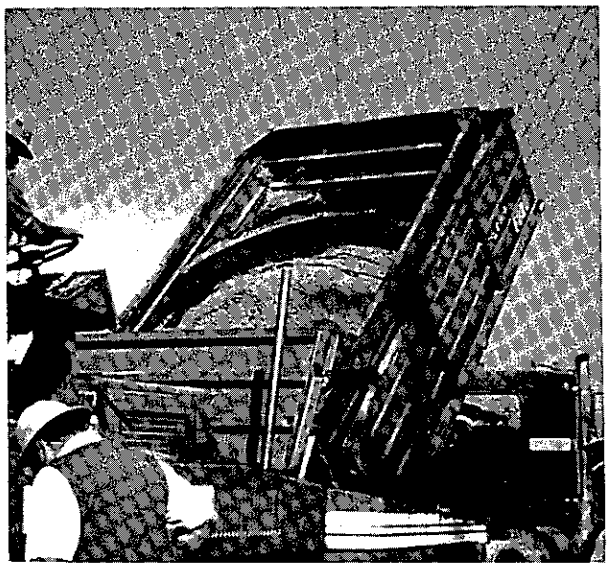
appeared to be well-coated. There was no drainage from the trucks nor any runoff as the trucks transported the material to the street. Subsequent testing of the mix (see Table 5) indicated that there was an excessive variation of gradation and binder content.

Paving Operation

The ambient air temperature during the paving operation ranged from 52°F (11.1°C) at about 5:00 a.m. to 85°F (29.4°C) at around 3:00 p.m. There was no wind and the skies were clear. The surface of each load had a grayish appearance which extended about 1/2 inch (12.7 mm) below the surface (Figure 12).



Gray Appearance of Surface
Figure 12

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Table 5

Mixture Placed in Street

Test No.	Aggregate Gradation (% Passing) 3/4" (19.1mm)	1/2" (12.7mm)	3/8" (9.5mm)	#4	8	16	30	50	100	200	% Ext. Asphalt	Stab.* 140°F (60°C)	Sp.Gr.
762-39	100	91	83	66	50	40	30	18	11	7.5	5.4	35 34	2.26 2.24
762-40	100	96	86	64	48	38	28	18	10	7.2	4.8	46 40	2.26 2.28
762-49	98	78	61	35	23	18	14	10	8	5.6	6.4	-	-
762-50	100	88	70	46	32	25	18	12	8	6.3	5.1	-	-
762-51	100	91	81	63	47	36	25	15	9	5.8	4.6	-	-
762-53	100	85	70	42	31	24	18	13	7	5.3	4.8	-	-
762-54	100	86	72	48	35	28	20	13	8	5.7	4.8	-	-
762-56	100	93	82	51	38	30	22	14	9	7.0	5.1	-	-

*40,000 lb. static compaction
(18,144 Kg)

Core Data (Cored April 18, 1976)

Core No.	Lane	Station	Sp.Gr.(1) As. Recd.	Rel. Comp. (2)	Remarks	Test No.
1	3	65+75	2.14	90.6	Under traffic	762-148
3	3	68+74	2.12	89.9	Under traffic	762-149
7	3	76+30	2.14	90.6	No traffic	762-150
8	4	77+80	2.11	89.4	No traffic	762-151

(1) Per Test Method No. Calif. 308.

(2) Based on Laboratory Kneading Compaction with 5.2% AR-4000, (see Table 3) per Test Method No. Calif. 366.

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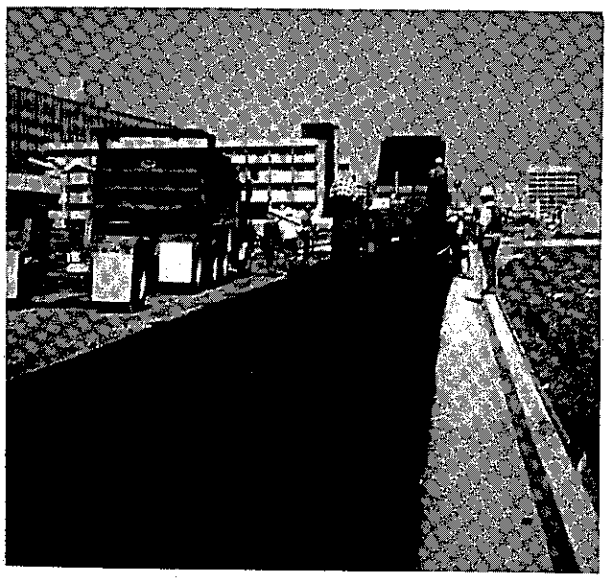
There was no evidence of drainage during transit, and only a small amount of clear water drained from the bed during unloading. Paving operations started in the lane next to the curb on El Segundo Boulevard and progressed north to Grand Avenue.

The Grand Avenue Intersection was skipped. The pavement was placed in one lift of 0.25 foot (76.2 mm). The mix was end-dumped into a Barber-Greene rubber-tired paving machine (Figure 13). No prime coat was used.



Paving Operations
Figure 13

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Compaction was provided by a 10 ton (9.08 metric ton) tandem for breakdown followed by a vibratory roller and then by a 10 ton (9.08 metric ton) "finish" tandem roller. The vibratory roller was a Dynapac CC42A. The rolling pattern was set according to the results of density tests using a nuclear gage. The target field density was 95% or more of the laboratory density obtained with a double plunger 40,000 lb. (18,144 Kg) static load applied at the rate of 0.25 in. (76.2 mm) per minute. The rolling pattern used consisted of breakdown coverage with the 10 ton (9.08 metric ton) tandem, 4 coverages with the vibratory roller and a final coverage with the tandem roller.. The mix seemed to compact very well and there was no evidence of runoff. A brownish appearance generally persisted for almost 24 hours followed by an intermittent grey appearance (Figure 14). In the grey areas, the surface was exceptionally friable and could easily be scuffed and abraded by foot pressure. In contrast, the brown areas scuffed only slightly under this foot pressure.

Curing Surface
Figure 14

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The first 100 feet (30.48 m) of pavement appeared very fine textured - more like a 3/8 (9.5 mm) or 1/2 (12.7 mm) inch-max. grading. Midway between Grand Avenue and El Segundo Blvd., a very coarse mixture was placed which seemed to represent a quantity equivalent to one batch. This area turned grey fairly quickly, thus indicating an early cure. As the trucks rolled over this area a high deflection was noted under the wheels. Another spot with high deflections was noted at a cross drain about 100 feet (30.48 m) south of Grand Avenue. After paving, excessive deflections in these areas were still noted which subsequently required replacement with new base material and hot AC.

About 100 feet (30.48 m) south of Mariposa Avenue in the outside lane away from the curb, bumps were created when the trucks dumped small amounts of mix onto the grade. This occurred as the trucks tried, by making quick stops, to dislodge mix adhering to the truck bed. When the paving machine progressed over these spots, bumps were created that were noticeable when driving over these areas the following day. The entire job, however, was rather rough riding, even for a leveling course.

Air Pollution

On this project there was no evidence of dust pollutants or air contamination of any kind at the plant or on the street. Also, according to the Douglas Oil Company representatives there was no cutter stock used in this emulsion.

Pavement Performance

Although the cold mix proposed by the Douglas Oil Company was not intended for use as surfacing, it was subjected to traffic

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for approximately a 40 day period. As curing progressed, the entire surface developed a greyish appearance similar to a cement treated base. The gray surface lacked cohesion and could easily be scuffed and abraded with foot pressure. In order to protect this surface, a fog seal was applied six days after construction using an SS-1 emulsion at the rate of 0.1 gallons per square yard (1.14 litres/m^2). Areas exhibiting high deflections during construction were dug out and replaced with good base material prior to the application of the hot AC and seal coat. Twenty-four hours after applying the seal, traffic was routed onto the cold mix. During the 40-day period traffic was permitted on this pavement, no significant distress other than slight surface tearing, which started after about 30 days, was noted (Figure 15).

Emulsion Mix After 35 Days of Traffic
Figure 15

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After 40 days, the entire cold mix section was overlaid with 0.25 foot (76.2 mm) of conventional hot 1/2-inch (12.7 mm) max. asphalt concrete without any further treatment of the emulsion mixture.

After 1 year, this project appears to be in excellent condition with no evidence of distress (Figure 16).

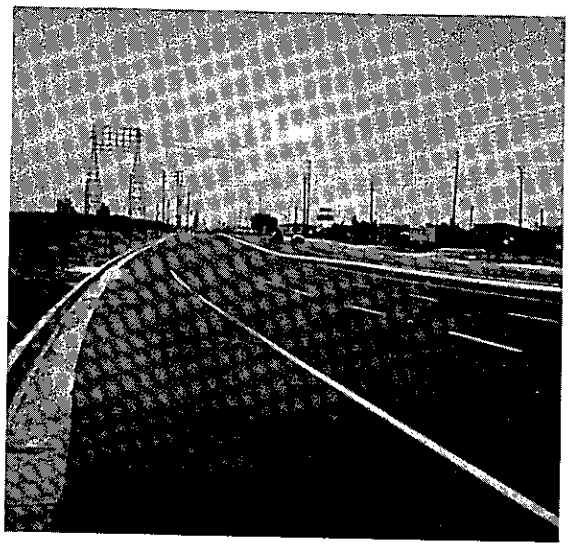

Figure 16

E. Cold-Mix Pavement Performance in the Pacific Northwest

The performance of cold mix open-graded pavements in the Pacific Northwest was reported as generally being very good in reference 5. Because of the difficulties encountered on the three Caltrans jobs described previously, a field review of several jobs located in Oregon and Washington was completed in June, 1976.

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The first cold mix pavement observed was adjacent to I-5 at the Glendale off-ramp in Douglas County, southwest Oregon. It was a 1.5 mile (2.41 Km) long 2-lane wide pavement (see Figure 17) placed in 1972 and designated County Route 313. Six percent emulsion was used for the 2-1/2" (63.5 mm) thick OGAC cold mix. The base consisted of 12 inches (.30 m) of 1" (25.4 mm) minus aggregate.

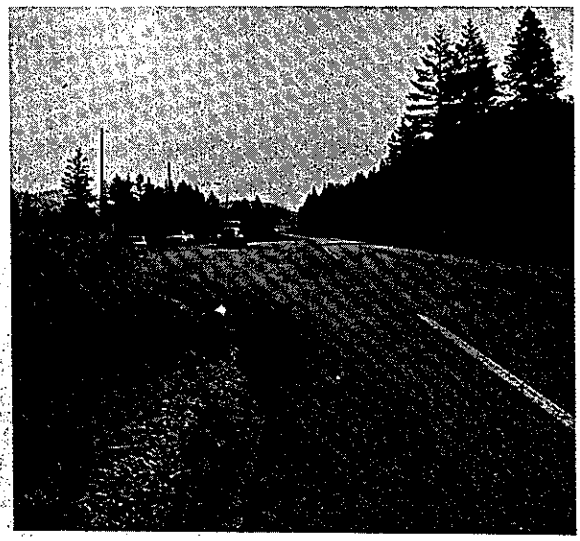

Figure 17

This pavement had been chip-sealed using CRS-2 emulsion. The pavement had a very coarse surface texture with some non-uniformity (see Figures 18 and 19). No major distress was noted. The coarse texture resulted in a somewhat noisy ride. Although very little traffic was observed on this road, the majority of the traffic it does carry was reported to be logging trucks. As this roadway is adjacent to I-5, the gross loads are supposed to be within legal limits.

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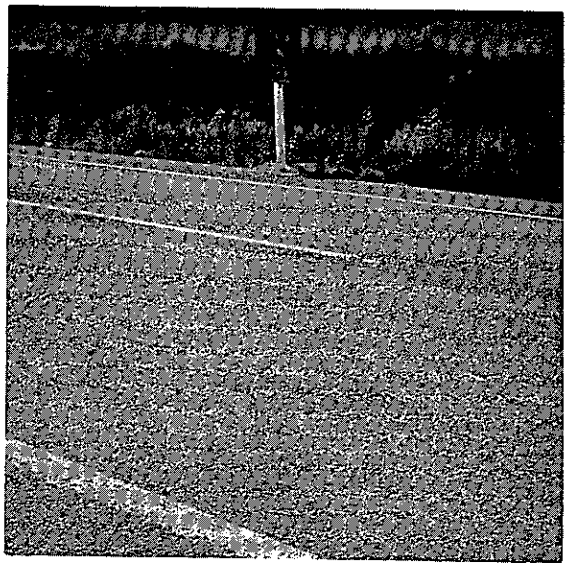

Figure 18

Figure 19

The second pavement observed was a chip-sealed OGAC cold mix on County Rt. 321 also located near Glendale. This job consisted of 16 lane miles (25.75 Km) of two-lane pavement placed in 1973 (see Figure 20). CMS-2 emulsion and 1-1/2% cement were used for the 2-3/4 inch (69.85 mm) thick pavement placed on 12-16 inch (12.7x6.4 mm) AB. A heavy choke had been used on this roadway followed by a chip seal using 1/2 x 1/4" (12.7x6.35 mm) chips. The OGAC aggregate came from Glendale and the chip seal aggregate from Grants Pass. This road is subjected to logging traffic and a few trucks were observed during the review (see Figure 21). The gross loads on these trucks supposedly approach 200 kips (91 metric tons), with the average being 150-160 kips (68-72 metric tons). The surface texture of this pavement appeared to be very good (see Figure 22). It was not as coarse as that on Rt. 313 but still appeared to be completely adequate. Again, no major distress attributable to the pavement was noted.

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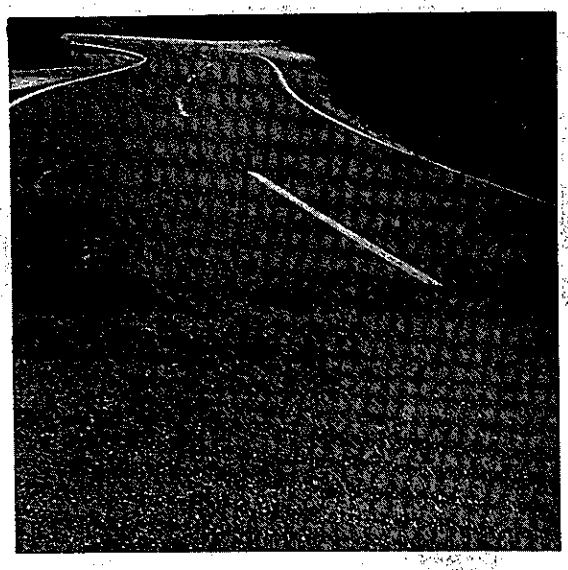

Figure 20

Figure 21

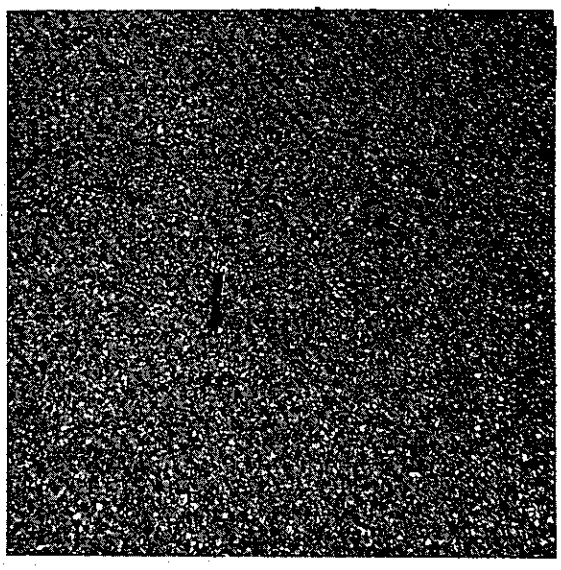

Figure 22

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Several test sections placed in 1973 on County Route 53 were also reviewed. CSS-1 emulsion was used in varying percentages for the OGAC cold mix test sections, followed by a chip seal in some cases. The aggregate used for both the OGAC and the chip seal was 3/4 inch (19.1 mm) minus, thus providing a coarse textured OGAC (see Figure 23, right side) and a very coarse chip seal (Figure 23, left side). Noticeable chip loss had occurred (see Figures 24 and 25). The texture appeared to be so coarse that it would be unlikely that the surface could withstand freeway traffic. Again, very little traffic was encountered when viewing this pavement.

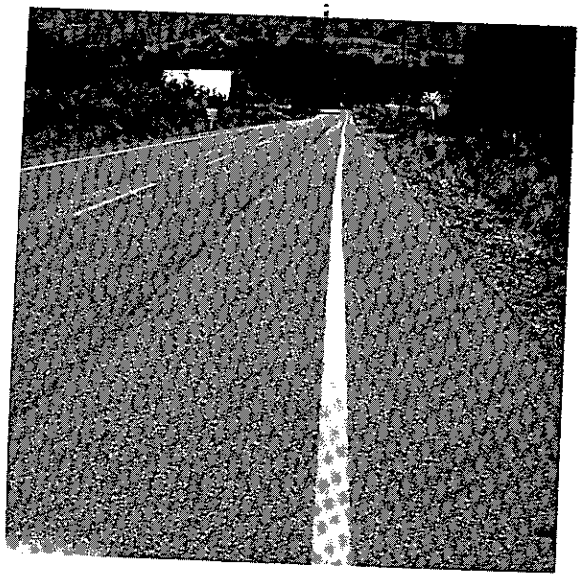

Figure 23

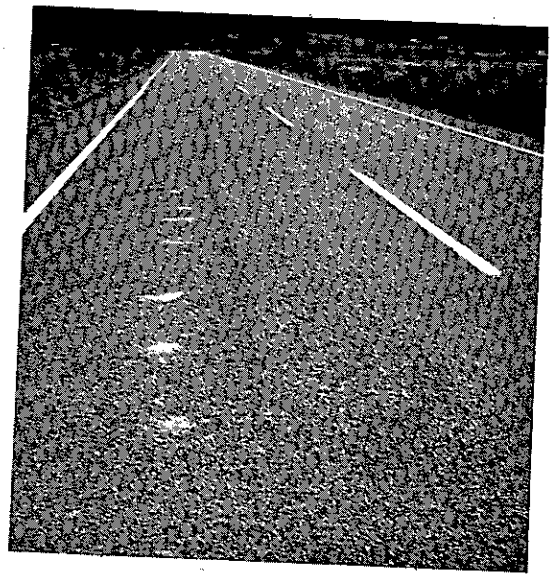

Figure 24

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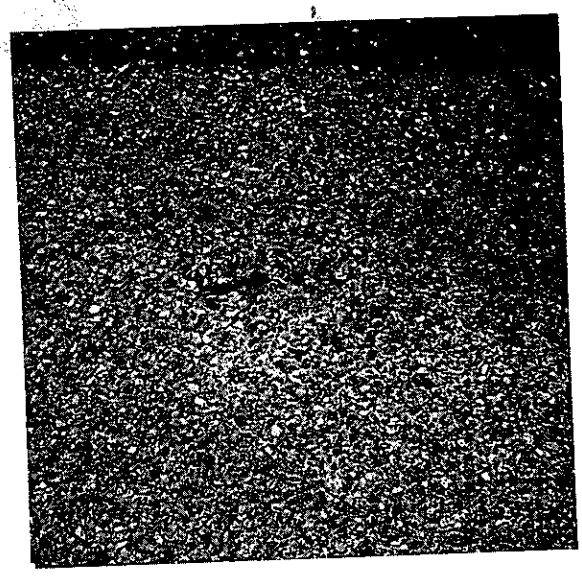

Figure 25

The last Douglas County pavement observed was on Route 4, also known as Diamond Lake Blvd. This 5-mile (8.0 Km) long 4-lane pavement was placed in 1971 and consisted of 3 inches (76.2 mm) of OGAC cold mix containing CMS-2. The center lanes in each direction were placed upon old pavement whereas the cold mix in the No. 2 lanes was supported by 12 inches (.30 m) of 1-1/2 inch (38.1 mm) max. Bituminous Treated Base. Due to problems with the large amount of stabilizer in some of the emulsion and the placement of the chip seal before the cold mix was completely cured, some AC instability developed in the lane used by the loaded logging trucks. An uneven profile developed that eventually required a hot mix blanket. Even the placement of the blanket did not completely eliminate the irregularities. The general condition of the pavement appeared to be very good with no other types of distress noted. A coarser surface texture was present on the shoulder as opposed to the traveled way (see Figures 26). This was caused, in part, by the use of County-supplied chips for the shoulder

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and Contractor-supplied chips for the traveled way. This roadway was the only Douglas County Route observed that bore a resemblance to typical Caltrans freeway conditions.

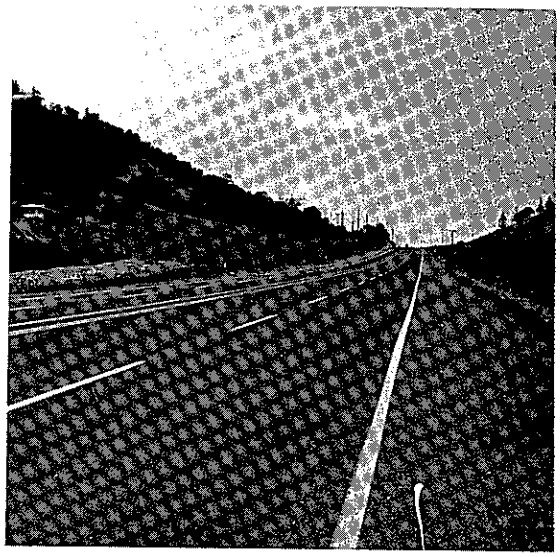

Figure 26

Cold open graded mixtures were considered by Douglas County personnel to be more versatile (patching, flexibility, and paving temperatures) than hot mixes and also were cheaper for the County because of the ability of the County to mix and place the cold mix using its own forces and equipment. However, emulsion mixtures were not considered particularly appropriate for high speed highways due to the necessity of periodically sealing the surface to prevent ravelling and the associated problems involving traffic control, chip loss, and windshield damage.

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It was found that very few roads had been constructed by the State of Oregon using cold emulsion mixtures. Cold mixes had, however, been used on a few secondary roads. Generally, cold open graded mix containing CMS-2 was used, followed by a chip seal in 2-3 weeks.

The first Oregon Highway Department test section observed was on I-80N east of Heppner Jct. and consisted of a BTB (Bituminous Treated Base) containing 5.5% SS-Kh emulsion. This base was placed in 1964. The aggregate was 3/4 inch (19.1 mm) maximum. The surface course was conventional hot AC. Absolutely no distress was observed at the location of this test section. The traffic at the time was light.

The second Oregon State Highway test section reviewed was located on FAS Route 911 between the community of Hermiston and the I-80N Meadow Valley Interchange. A two-inch (50.8 mm) thick cold-mix surface course was constructed on a two inch (50.8 mm) thick AB level course in 1969. It contained 1/2-inch (12.7 mm) maximum aggregate and approximately 6.5% CMS-2 (CM-K) emulsion. This was followed with a chip seal consisting of RS-3K emulsion and 1/4 inch (6.35 mm) x #10 aggregate. The surface of this roadway looked richer than most of the cold-mix pavements observed and the pavement was easy to penetrate with a knife blade. The observed traffic was moderate and consisted of several trucks. No distress was observed but there was some variation in surface texture across the pavement (see Figure 27). Although the surface was a little rich, the surface texture looked good (see Figure 28). The roadway appeared to be providing good service.

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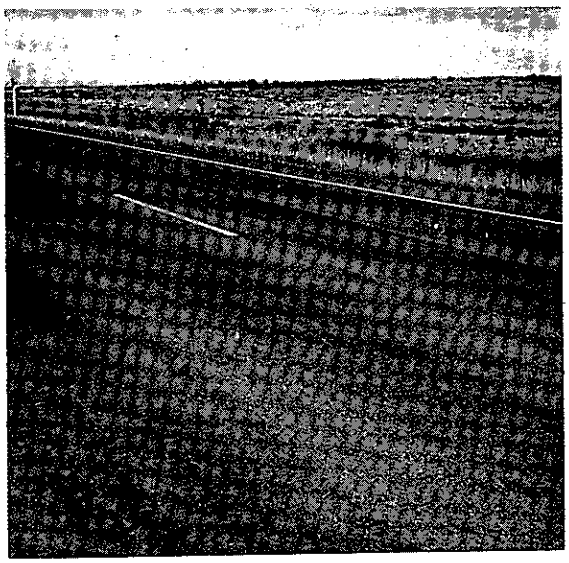

Figure 27

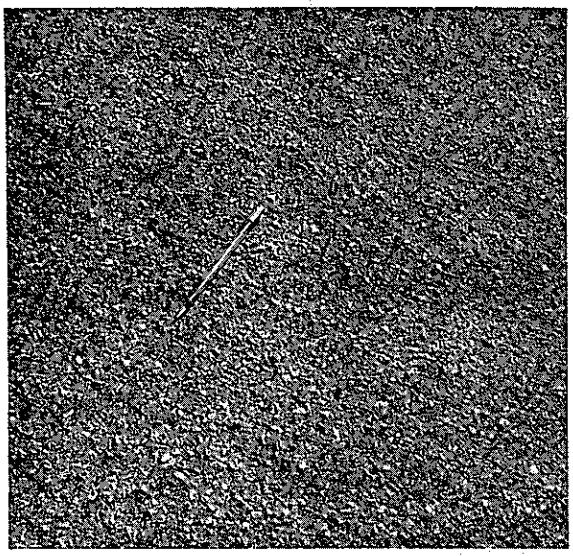

Figure 28

The third and last Oregon Highway Department test section observed was on FAS Route 829. This two-lane road was constructed in 1972 and consisted of a 2-inch (50.8 mm) thick cold-mix surface placed mostly upon old AC. CMS-2 emulsion was used at the rate of approximately 6.5%. The aggregate was 3/8 inch (9.5 mm) max. A chip seal was then placed using CRS-2 and 1/4 inch (6.35 mm) x #10 chips. This pavement was also in good condition. The pavement appeared a little dry but no distress was observed. The surface texture was somewhat nonuniform but no raveling or bleeding was observed (see Figures 29-31). There was almost no traffic on this road at the time of this review. During the 30-40 minute period, two vehicles were encountered.

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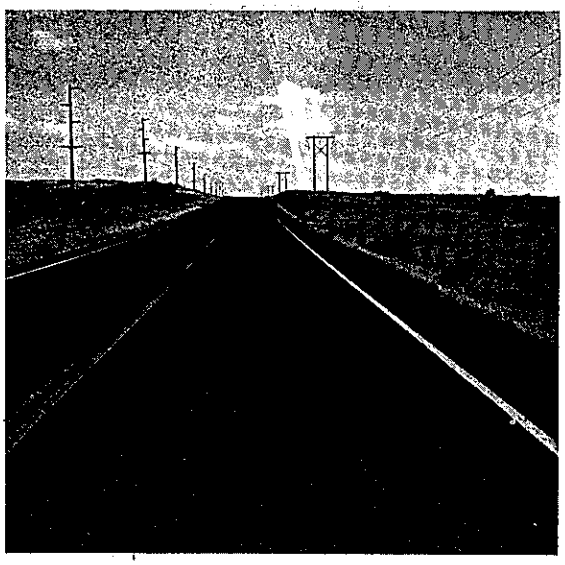

Figure 29

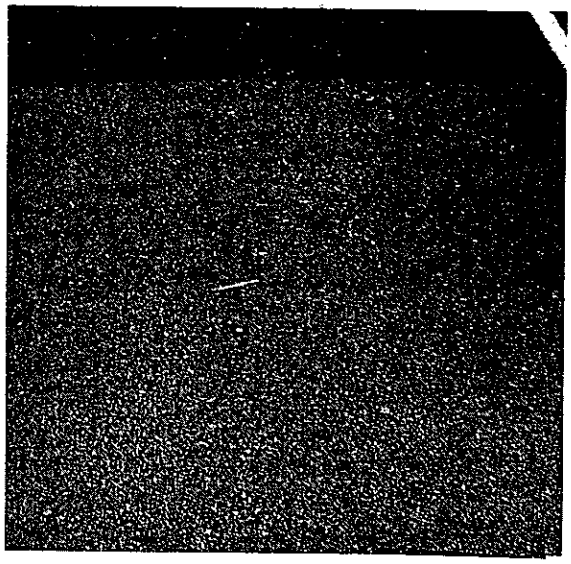

Figure 30

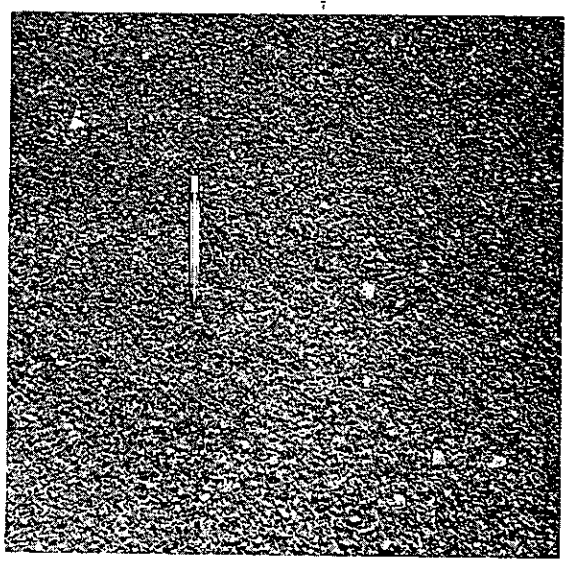

Figure 31

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Several pavements in the Gifford Pinchot National Forest in Washington were also viewed. Very little traffic was encountered on these roads during the review. The traffic that was encountered consisted of occasional logging trucks and some light traffic. The first of the three cold mix National Forest jobs observed was referred to as the Canyon Creek job on Routes N-54 (4.7 miles [7.56 Km]) and N-56 (2.1 miles [3.55 Km]). The pavement was placed in 1972 and consisted of two 2-inch (50.8 mm) lifts placed on 1-inch (25.4 mm) minus aggregate base (AB) which was in turn placed upon 8 inches (203.2 mm) of 2-inch (50.8 mm) minus AB. A Blaw-Knox P.F.500 paver and a Calenco pug were used. Traffic (logging trucks) were supposedly using this pavement before the compaction was completed. A chip seal (3/8-inch [9.5 mm] max.) was placed a short time after the cold mix was constructed. Since 1972, an estimated 99 million board feet had been hauled over these roads. There was noticeable variation in the surface texture with the denser portions appearing marginal from a skid resistance standpoint (see Figures 32 and 33). Figure 34 shows the pavement after a light rain and illustrates the smoother texture observed on Route N-56. Note the standing water on this sealed OGAC. Scuffing and raveling was observed with most of this located in turns. Pumping and stability problems were observed but these were not attributed to any characteristics of the mix other than the extent to which surface water penetrated through the AC into the underlying structural section.

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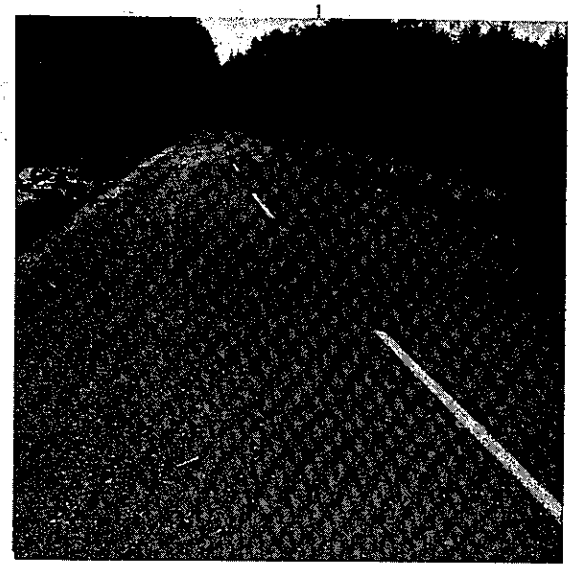

Figure 32

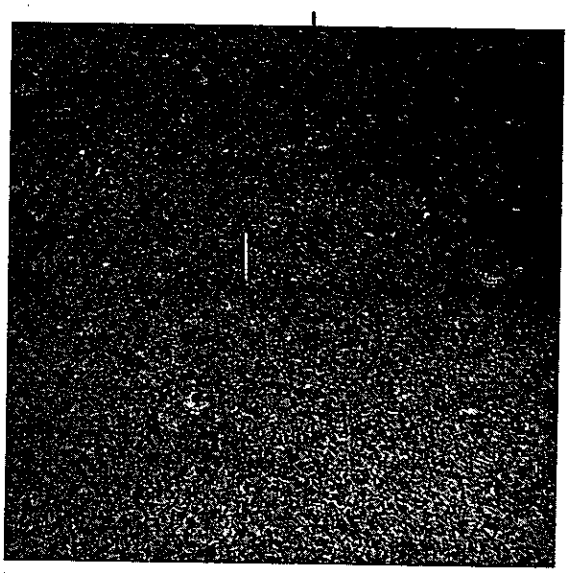

Figure 33

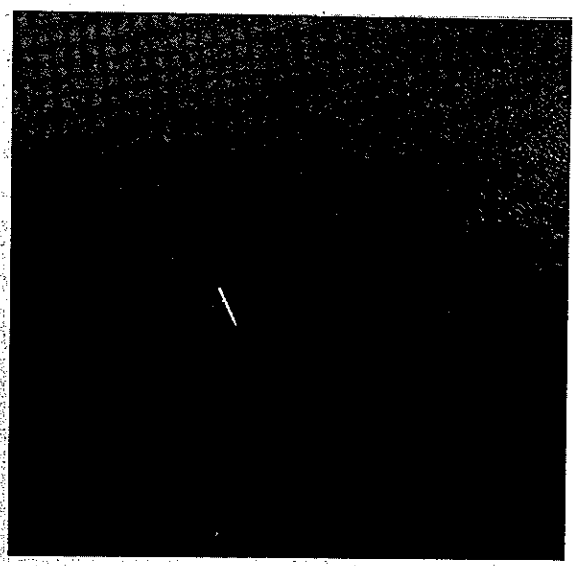

Figure 34

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The next cold mix pavement observed was located on the Lewis River Road. It was designated as Route N-90 and had been constructed in 1970. The surface consisted of two 4-1/2 inch (114.3 mm) thick lifts of cold OGAC. CMS-2 emulsion and 1-1/4 inch (31.8 mm) x #10 aggregate were used for the 15.6 mile (25.1 Km), 2-lane road. An 850 TPH (772 metric tons/hr) Eagle pug was used with Barber Greene, Cedarapids, and Blaw-Knox pavers. The aggregate used for this job supposedly could not be used for hot mix due to stripping. Problems with a stiff mix were encountered, however, that required the addition of solvent on the job. The pavement was chip sealed the following season and a portion had received a second seal. The cold mix was originally intended as a BTB for hot DGAC but the hot mix has not been required. The traffic on this road was primarily logging trucks reported to weigh up to 200 kips (90.7 metric tons). The ADT was 280 during the 10-mo. logging season. An average load was 160 kips (145 metric tons). This was the most heavily loaded pavement in this area from a TI standpoint and the design life had already been realized. The pavement was in fairly good condition although it appeared to be very dense (see Figures 35 and 36). Distress was again noted in several locations that appeared to be water-associated foundation failures. Access of surface water through the pavement may have been a contributing factor if the "seal" was not impervious. No distress of significant severity was observed that could be assigned exclusively to the mix design.

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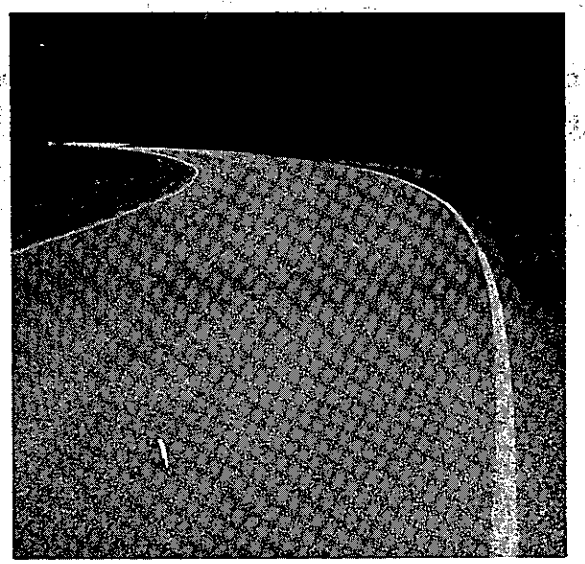

Figure 35

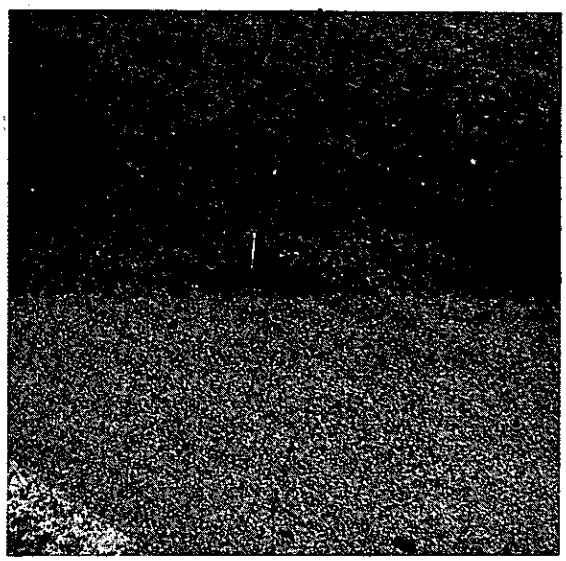

Figure 36

One other pavement was briefly examined. It was Route N-818, known as the Merrill Lake Road and was constructed in 1972. It consisted of 4 inch (101.6 mm) cold OGAC, then 2 inch (50.8 mm) cold OGAC, then a chip seal (3/8 inch [9.5 mm] chips). Various bases were beneath the pavement. Forty-two million board feet had reportedly been hauled over this roadway. The end of the project observed was in good condition with no distress noted, and a very satisfactory surface texture appearance (see Figure 37).

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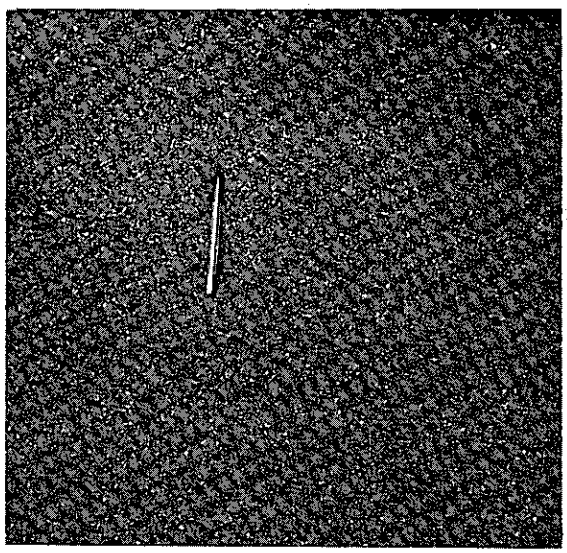

Figure 37

Several cold-mix pavements in the Mt. Hood Forest were also observed. The first project visited in the area was referred to as the Bull Run River Road (Route S-10.1). The pavement on this one-lane road consisted of cold DGAC. It was placed in 1971 to get some experience with cold mix paving. One-inch (25.4 mm) max. aggregate was used. There was very little traffic on this road due to controlled access at each end. Only official traffic and logging traffic were permitted to use the road. The 1974 traffic consisted of about 50 loaded logging trucks per day. Only about 25 loaded trucks per day were using the road in 1976. The overall condition of the pavement was fair. There were noticeable surface texture variations, some raveling, and some other distress less attributable to the mix design. The surface texture was coarse (see Figures 38-40). Although this pavement was scheduled for a surface treatment soon, the binder was still somewhat pliable. However, it was fairly easy to pick out individual aggregate particles.

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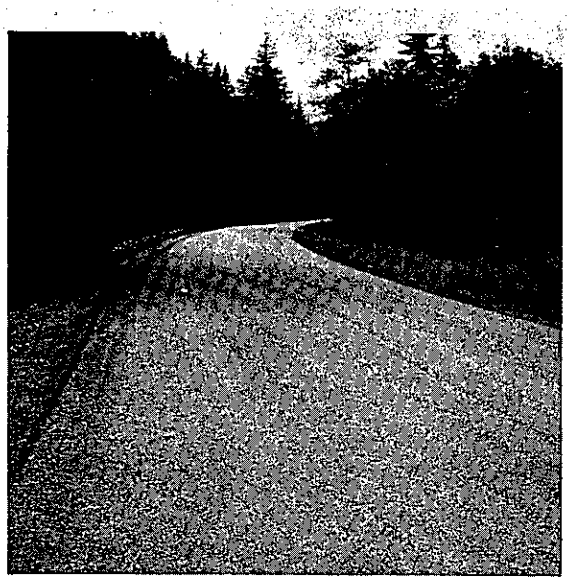

Figure 38

Figure 39

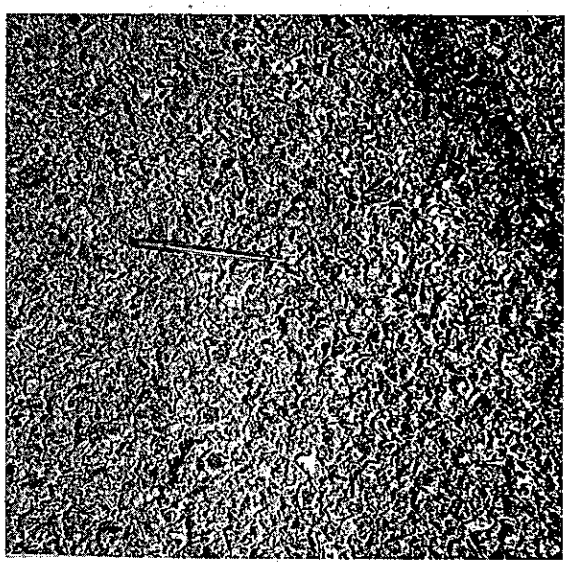

Figure 40

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The next project observed was Route S-154 (see Figure 41). This one-lane wide, 4-mile (6.4 Km) long pavement was constructed in 1973 using 5% CMS-2. Two 2-inch (50.8 mm) lifts of cold OGAC were placed. The mix contained one-inch (25.4 mm) max. aggregate. The pavement was then sealed with a chip seal. The surface texture of this pavement was very coarse (see Figures 42 and 43). The roadway was in fairly good shape but did contain some distressed areas and some patches. No traffic was encountered during the survey.

Figure 41

Figure 42

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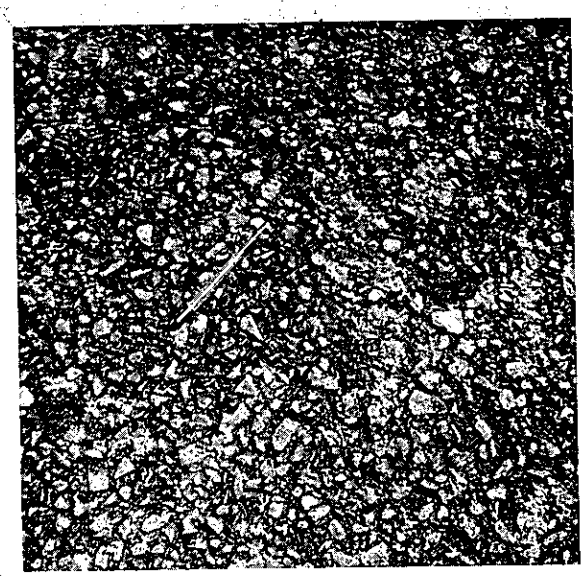

Figure 43

The third and last route observed in this controlled access area was Route S-10. This 3-inch (76.2 mm) thick cold DGAC (sand mix) was placed in 1967 using CSS-1 emulsion. Route S-10 received no chip seal and, as a consequence, had a very dense surface (see Figures 44 and 45). Considerable alligator cracking was observed but no instability was evident.

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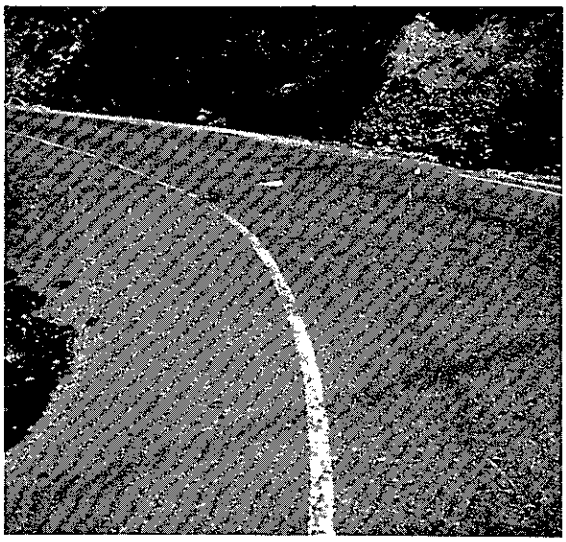

Figure 44

Figure 45

Route N-12 (see Figure 46), which was located immediately outside the controlled access area, contained essentially the same pavement but had been chip sealed. Its surface texture was noticeably coarser than that of Route S-10 (see Figure 47). The traffic on Route N-12 was considerably more than that within the controlled access area but would still be considered light.

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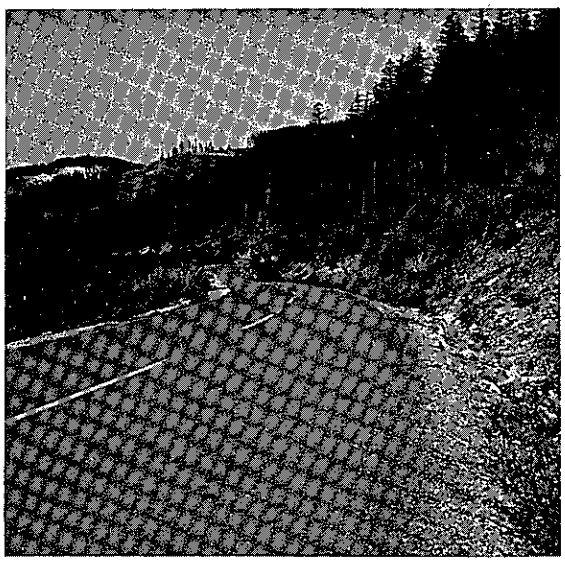

Figure 46

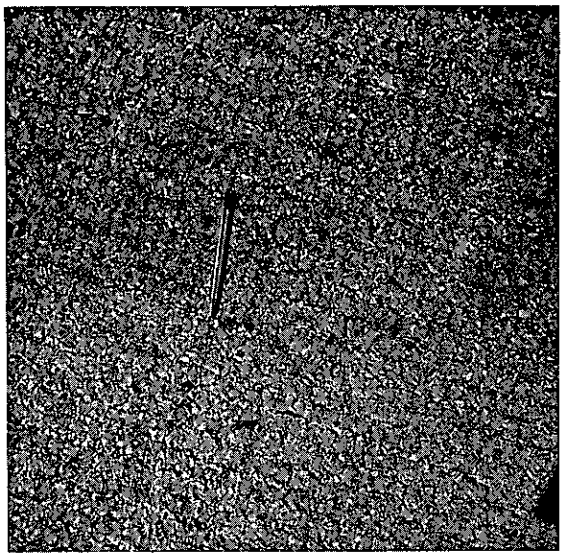

Figure 47

General discussions with personnel in the Mt. Hood Forest indicated that they generally preferred hot mix over cold mix. One of the reasons for this difference between the Gifford Pinchot personnel's preference for cold mix and this preference for hot mix in the Mt. Hood Forest was hot mix availability. Hot mix is readily available in the Portland area and, as such, often used in the Mt. Hood Forest. Often, hot <u>or</u> cold DGAC or OGAC could be used, however, in their opinion. When working with the cold mix, more mix variation had been encountered than with hot mix. This was attributed, in part, to the single stockpile cold feed control used for cold mixes. Flush and chip seals were being used extensively in the Mt. Hood Forest with very satisfactory results.

The last cold mix project observed was located in the Deschutes National Forest southwest of Bend, Oregon. Prior to viewing this job, discussions with various USFS personnel in Bend revealed that both DGAC and OGAC emulsion mixes had been used in the Deschutes Forest with both good and bad

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results. Problems attributed to lack of experience on the part of contractors had been encountered. On occasion, BTB mixes with relatively low residual asphalt contents had been tried as surface courses but this had not been successful.

USFS Route 2301 (see Figure 48) consisted of a cold mix beneath a very coarse chip seal (3/4" [19.1 mm] x #10). Thus, a very coarse texture was observed between the wheel tracks (see Figure 49). The texture was finer in the wheel tracks (see Figure 50) and further into the job. The asphalt was very soft and pliable and, in fact, asphalt blisters were observed in some locations. Occasionally, the seal was spalled but no major distress was observed. Very little traffic was encountered - two light vehicles and two logging trucks during 30-40 minutes on the job.

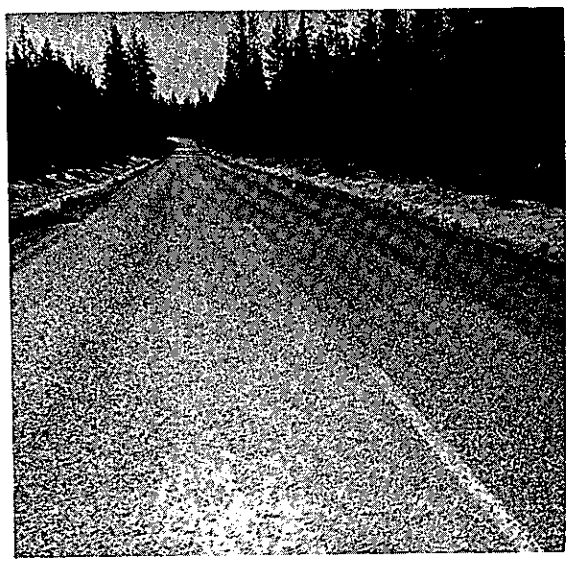

Figure 48

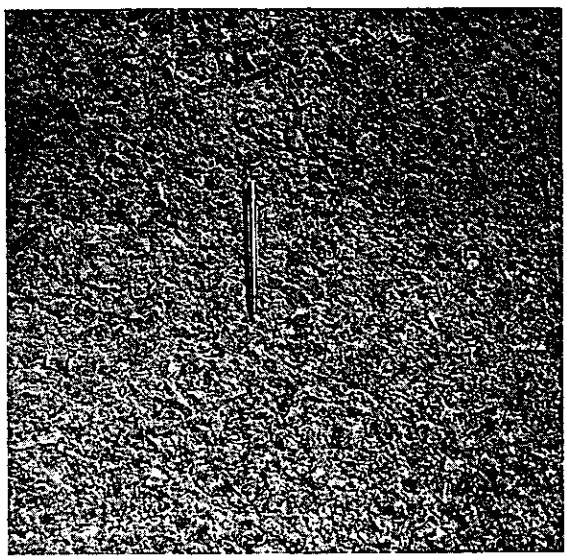

Figure 49

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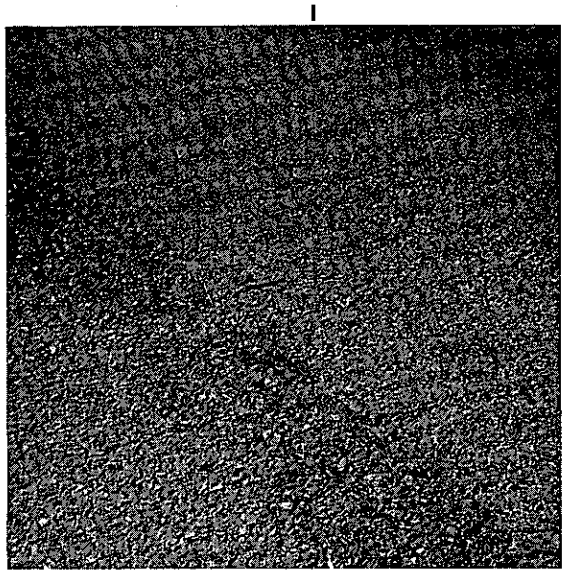

Figure 50

Thus, in general, it was found that cold mix asphalt concrete is not being used on mainline highways in the Pacific Northwest. With rare exception, its use is confined to low volume, low speed roads. However, in many cases logging trucks that exceed the legal limit are using these roads. Chip sealing and/or heavy fog sealing (referred to as flush seals) are used extensively. Most of the emulsion mixtures are an open graded type of mixture containing a gradation of about 3/4" (19.1 mm) by No. 10. CMS-2 and CMS-2S emulsion are used almost exclusively. CMS-3 emulsion has been used on one or two projects but apparently was not too successful and no additional work with this grade was mentioned. The design procedure for open graded mixtures varied between organizations but basically was the same approach used by California for open graded mixtures. Essentially, the amount of emulsion used in a mixture to serve as surfacing is all that the particular aggregate will hold without excessive drainage. The method of determining retention capabilities is by measurement of drainage under a given

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set of conditions such as sample size, temperature, and time. As a consequence, for open graded mixes in these areas, 6.0% emulsion is frequently used. This results in a residue of about 3.6% asphalt. The seals are used to compensate for this low asphalt residue.

Most of the emulsion mixtures observed had been placed in one 2-to-3 inch (50.8-76.2 mm) thick lift. Occasionally, thicker sections were placed but in two or more lifts. Whenever more than one lift of open graded was used, paving delays were generally not necessary due to the faster "break" of the emulsions used. Generally, however, delays for curing had not been a problem. All the agencies had occasionally sealed new pavements before the lower portion of the mix was completely cured. Some areas still supposedly contained emulsion in the lower portion of the mix a year after sealing. However, no problems such as ravelling or rutting were reported. Their experience with CMS grades of emulsion indicated that sufficient adhesion develops within 4 or 5 hours so that the pavement will not be damaged by unexpected rain thereafter.

In general, a heavy sand choke was favored. However, there was not unanimous agreement on this subject. Most everyone agreed that unless a fog seal is blotted by sanding or allowed to cure, pick-up by rubber tires could destroy the surface. Yet, recommendations in many instances were that a choker or blotter sand not be used. Thus, whether or not to use a choker sand seems to be rather controversial. Steel-wheel rolling was preferred to rubber tire rolling in most cases.

In summary, it appears that the agencies visited in Oregon and Washington have generally been obtaining satisfactory performance from emulsion mixes. However, traffic conditions

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were so radically different from California highway conditions that a direct comparison should not be made. Their roads, for example, are sparsely used. Logging trucks carry extremely heavy loads but generally at relatively low speeds. Due to the low traffic volume, lanes can be blocked for sealing operations (fog or chip seals) for extended periods of time. As an example, in the Mt. Hood Forest one sealing operation that has worked well involves diluting a slow setting emulsion 10:1 with water and applying multiple coverages over several weeks until the pavement is sealed. This would be prohibitively expensive and, for all but the most remote Caltrans routes, very difficult to accomplish due to traffic control problems.

F. Mix Design Procedure and Field Control Requirements

One of the major difficulties encountered when developing a mix design for a dense graded or open graded cold mix is the absence of a proven mix design procedure. The lab mix design procedure used by Douglas County, Oregon, for emulsion mixtures includes checking the SE and aggregate gradation, then mixing several 5000 gram batches containing various amounts and grades of emulsion in the Hobart mixer. Generally CMS-2, CMS-2S, and CSS-1 are tried. Each batch is then placed on a plywood board in a pile about 2 inches (50.8 mm) high, 4 inches (101.6 mm) wide, and 8 or 9 inches (203.2mm or 228.6 mm) long. No compaction other than general hand compaction with a piece of plywood to form the test specimen is provided. Immediately after forming, an inspection for drainage is made. If any runoff is noted, either less emulsion is used or 1-2% cement is added to the mix to act as a blotter. After approximately two hours air cure, the mix is pushed off the plywood and the unsupported length at the time of fracture is noted. The type of fracture is also noted. This provides a measure of strength and flexibility,

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both of which are used to select the mix design. However, problems are often encountered due to nonuniformity in emulsion even though it all presumably complies with the specifications so field adjustments are often required.

The mix design procedure used by the FHWA Laboratory in Vancouver, Washington, is also not very sophisticated. For example, no stability, immersion compression, cohesion or R-value tests were being used for routine mix design in June, 1976. R_T values (a term that combines stability and cohesion into a single value - see Reference 6) have been considered but this characteristic has not been a reliable indicator of the performance of cold mixes. The use of the Resilient Modulus approach described by Schmidt (7) was considered promising, however. Although procedures have also been published for bituminous treated base mix design (6,8,9), the need for trial and error adjustment during each of the three Caltrans' field jobs described previously substantiated the contention that additonal work was required to develop a reliable and meaningful cold mix surface course design procedure.

Several individual problem areas had been revealed during the field trials. One of the most critical involved the apparent dependency of CMS-2 solvent content on the ability of the emulsion to coat aggregate of the type encountered at Pacifica. This experience suggests the need for lab testing of the emulsion and aggregate to be used for the work to avoid coating difficulties on the job.

Because cold-mix surface courses will be subjected to the same environmental and load (traffic) associated stress as hot mix surface courses, it would appear that the aggregate quality specifications should be the same for both types of mixes.

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While it may be true, at least in some cases, that the base stock used in emulsions does not harden during the manufacture of the emulsion as much as if it were heated in a pugmill, this is not always true. Table 6 contains data from the Fontana project that indicates that substantial hardening of the asphalt in the emulsion had occurred. It is not, therefore, a valid argument that the lower density common to emulsion mixtures will not be particularly detrimental to the durability and life expectancy of the pavement due to the avoidance of the asphalt hardening that normally occurs in the pugmill. Thus, the proper amount of emulsion for a given mix would appear to be somewhat more than that required to provide an asphalt residue equivalent in volume to that which would be recommended for a hot mix containing the same aggregate. This was confirmed, at least to some extent, by the satisfactory performance of the Sepulveda test section that was designed in this manner. However, emulsions are roughly 40% water and most dense graded emulsion mixtures require some pre-mix moisture to prevent premature breaking of the emulsion. A total amount of liquid equal to 10 or 12 percent, therefore, is not uncommon with dense graded emulsion mixtures. Thus, the compaction and free drainage of dense graded emulsion mixtures becomes somewhat of a problem both in the laboratory and in the field. Because of this, three different methods of compaction were examined regarding the selection of the appropriate amount of pre-mix moisture and field control of pavement density when constructing dense graded cold mix AC.

The three compaction procedures used were kneading compaction, 50-blow Marshall compaction, and double-plunger static compaction. Fluid was exuded regardless of the compaction procedure used (Table 7). However, the amount of fluid exuded was considerably less when using the static compaction approach than when the other two methods were used. Thus, this approach

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Table 6

RECOVERED ASPHALT PROPERTIES

Open Graded Mix

Location Station	Emulsion* Type	Emulsion* %	Penetration 7 Day	Penetration 1 Year	Softening Point 7 Day	Softening Point 1 Year	Ductility 7 Day	Ductility 1 Year
1+50 WB	CMS-2H	7.0	40	23	128	147	150	100+
7+00 EB	CMS-2H	6.5	32	18	132.5	146	150	100+
10+00 Ctr	CMS-2H	6.5	25	14	136	153	150	43
13+00 WB	CMS-2H	7.0	25	15	137	153	150	28
25+00 WB	CMS-2H	6.5	26	19	138	152	150	45
Average of Recovered Penetration			30	18				

Dense Graded Mix

Location Station	Emulsion Type	Emulsion %	Penetration 7 Day	Penetration 1 Year	Softening Point 7 Day	Softening Point 1 Year	Ductility 7 Day	Ductility 1 Year
18+00 Ctr	CSS-1H	8.0	54	20	122	130	150	100+
26+00 EB	CSS-1H	8.0	46	15	123	151	150	100+
32+00 WB	CSS-1H	8.0	33	21	131	146	150	100+
35+00 EB	CSS-1H	8.0	33	27	130.5	145	150	100+
Average of Recovered Penetration			42	21				

*Base asphalt used for CMS-2H was 40-50 pen; base asphalt used for CSS-1H was 60-70 pen.

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Table 7

Moisture Exuded During Compaction
(Lab Tests)

Compaction Method	Binder Grade	Binder %	Premix Moisture	Total % Liquid	Total Grams	*Moisture Exuded Grams	*Moisture Exuded %
Kneading	CSS-1	8.0	3.0	11.0	115	15	13.0
Marshall	CSS-1	8.0	3.0	11.0	115	10	8.7
Static	CSS-1	8.0	3.0	11.0	115	5	4.3
Kneading	CSS-1	9.0	3.0	12.0	126	16	12.7
Marshall	CSS-1	9.0	3.0	12.0	126	16	12.7
Static	CSS-1	9.0	3.0	12.0	126	9	7.1
Kneading	CSS-1	10.0	3.0	13.0	137	20	14.6
Marshall	CSS-1	10.0	3.0	13.0	137	17	12.4
Static	CSS-1	10.0	3.0	13.0	137	12	8.8

*Based on total liquid content.

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would be preferable if any subsequent tests were conducted on the uncured test specimen because of the minimal loss of emulsion during compaction. The results presented in Tables 8 and 9 indicate that the greatest density will be obtained with the kneading compactor. The density obtained with the Marshall equipment was the least in all cases and this density most closely approximated the density measured in the field (Table 10). The densities obtained with the static compactor were generally slightly less than those obtained with the kneading compactor. To avoid the probability of occasionally obtaining field relative compactions in excess of 100% and to avoid requiring the use of the more complex kneading compaction equipment, it is suggested that the static double-plunger approach be used. The results of the testing summarized in Table 11 suggest that an appropriate amount of pre-mix moisture would be that amount resulting in the exudation of 2-10 grams of fluid during the application of the 40,000 pound (18,144 Kg) static load, at a loading rate of 0.25 inches (6.35 mm) per minute. Thus, the recommended laboratory mix design procedure would be to (1) Select an emulsion content that will provide a residual asphalt content equivalent to that required for a hot mix containing the same aggregate, (2) Hand mix several batches of the job aggregate using the recommended emulsion content and pre-mix moisture contents varying from 1 to 6% (in 1% increments) and select the lowest pre-mix moisture content that provides 2-10 grams exuded fluid when consolidating the mix using the double-plunger system, and (3) Calculating the density of the briquette containing the optimum amount of emulsion and pre-mix moisture to determine the laboratory maximum density. It is recommended that a field relative compaction requirement of 95% of <u>this</u> maximum laboratory density be required. Comparison of the field data in Table 10 with the corresponding laboratory data in Table 9 indicates that the El Segundo pavement would have complied

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Table 8

Laboratory Mix Density
(Sacramento Aggregate Source)

Compaction Method	Density	Hot Mix (AR-4000)	Hot Mix (Ar-2000)	Cold Mix CSS-1h
*Kneading (150 blows 500 psi)	Specific Gravity	2.38	2.38	2.29
	% Rel. Compact.	100	100	96.2
Marshall (50 blows @ side)	Specific Gravity	2.34	2.34	2.17
	% Rel. Compact.	98.3	98.3	91.2
*Static (40,000 lbs. double plunger, 0.25-in./min	Specific Gravity	2.31	2.33	2.28
	% Rel. Compact.	97.0	97.9	95.7

Notes:

1. Hot mix binder content was 5.5% by dry wt. of the aggregate.
2. Cold mix contained 9.0% emulsion and 1.0% premix water.
3. Residue by distillation of CSS-1h emulsion used was 61.4%.
4. Hot mix was compacted at 230°F (110°C).
5. Cold mix was compacted at 77°F (25°C) then cured for 72 hrs. at 100°F (37.8°C).
6. All mixes contained aggregate complying with the requirements of section 39 of the Standard Specifications (2) for 1/2-inch (12.7 mm) max, medium grading.

*Pounds per sq. in. = 6.894757 Kilopascals
Pounds = .4536 Kilograms
Inches = 25.40 Milimetres

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Table 9

Laboratory Mix Density
(El Segundo Test Section)
Lab Data

Compaction Method	Density	Hot Mix (AR-4000)	Cold Mix (Docal 1054)
*Kneading (150 blows @ 500 psi)	Specific Gravity % Rel. Compact.	2.36 100	2.31 97.8
Marshall (50 blows @ side)	Specific Gravity % Rel. Compact.	2.32 98.3	2.15 92.7
*Static (40,000 lbs. double plunger, 0.25-in./min)	Specific Gravity % Rel. Compact.	2.26 95.8	2.23 94.5

Notes:

1. Hot mix binder content was 5.0% by dry wt. of the aggregate.
2. Cold mix contained 8.5% emulsion and 3.0% premix water.
3. Residue by distillation of Docal 1054 emulsion was 59.4%.
4. Hot mix was compacted at 230°F (110°C).
5. Cold mix was compacted at 77°F (25°C) then cured for 72 hrs. at 100°F (37.8°C).
6. All mixes contained 1/2-inch (12.7 mm) max. aggregate from the job site.

*Pounds per sq. in. = 6.894751 Kilopascals
Pounds = .4536 Kilograms
Inches = 25.40 Milimetres

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Table 10

Cold-Mix DGAC Field Density
(El Segundo Test Section)

Station	Distance Rt. of ℄ Feet	Distance Rt. of ℄ Metres	Nuclear Gage Density lbs/ft3	Nuclear Gage Density Kg/m3	Relative Compaction* (%) A	Relative Compaction* (%) B
54+70	45	13.7	134.2	2149.9	91.1	96.4
"	56	17.1	142.3	2279.6	96.6	102.2
56+00	45	13.7	138.5	221.87	94.0	99.5
"	56	17.1	132.3	2119.4	89.8	95.0
60+50	45	13.7	136.0	2178.7	92.3	97.7
"	56	17.1	135.4	2169.1	91.9	97.2
67+00	45	13.7	134.8	2159.5	91.5	96.8
"	56	17.1	132.9	2129.1	90.2	95.4
71+36	45	13.7	136.7	2189.9	92.8	98.2
"	56	17.1	137.9	2209.2	93.6	99.1
77+75.50	45	13.7	134.2	2149.9	91.1	96.4
"	56	17.1	137.3	2199.5	93.2	98.6
Average			136.0	2179.3	92.3	97.7

Station	Lane No.	(6"(152.4mm)Dia. Cores) Density lbs/ft3	(6"(152.4mm)Dia. Cores) Density Kg/m3	Relative Compaction (%) A	Relative Compaction (%) B
65+75	3	133.5	2138.6	90.6	95.9
68+64	3	132.3	2119.5	89.8	95.0
76+30	3	133.5	2138.7	90.6	95.9
77+80	4	131.7	2109.8	89.4	94.6
Average		132.8	2126.7	90.1	95.3

*A Kneading Compaction = $\frac{\text{Field Density}}{\text{Density of hot mix with 5.0\% (AR-4000)}}$

B 40,000 lb(18,144 Kg) Static Load = $\frac{\text{Field Density}}{\text{Density of emulsion mix after curing 72 hours @100°F (8.5\% emulsion - 3\% moist)}}$

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Table 11

Pre-Mix Moisture vs. Exuded Moisture

At Optimum Emulsion Content

Specimen Desig.	Percent Pre-Mix Moisture Added	Specimen Weight - Gms			Remarks
		Before Compaction	After Compaction	Loss	
A	0	1290	1290	0	Both A&B balled up initially, then mixed well. Estimated 98% coating.
B	0	1293	1293	0	
C	1.0	1305	1304	1.0	Both C&D mixed well. Estimated 100% coating. Exudation began at 35,000 lbs.
D	1.0	1304	1303	1.0	
E	2.0	1317	1312	5.0	Both E&F mixed well. Estimated 100% coating. Exudation began at 15,000 lbs. This combination was best.
F	2.0	1317	1308	9.0	
G	4.0	1338	1315	23.0	Both G&H mixed well. Estimated 100% coating. Exudation began at 6000-9000 lbs.
H	4.0	1338	1313	25.0	

Notes:

1. Mix contained 8.2% CSS-1h. Asphalt content was (8.2)(.583) = 4.8%.

2. Moisture content of "dry" aggregate was 0.2%.

3. Mixed by hand using spatula and bowl for 1-min. pre-mix after addition of moisture, then 4.5 additional minutes after addition of emulsion.

4. Compacted using double plunger; 40,000 lb (18,144 Kg) load applied at rate of 0.25 (63.5 mm) inches per minute.

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with this proposed requirement. However, even compliance with this requirement will provide cured-out cold mix densities substantially less than those generally accepted for hot mix. For example, the data in Table 9 indicates that a typical cured-out cold mix density would be (0.95)(0.94) or 89.3% of the max laboratory density for hot mix (Kneading Compactor) containing the same aggregate. This is substantially less than the desired 95% relative compaction for hot mix and will no doubt result in a substantially greater rate of hardening for the in-service cold mix binder, and possibly other problems related to permeability. It appears, therefore, that serious consideration must be given to the use of construction seals, as is common in the Pacific Northwest, to partially offset the effect of this considerably greater void content in dense-graded cold mix upon the rate of hardening of the binder. If seals are necessary, it would, of course, increase construction costs.

The design of cold-mix open graded AC is concerned primarily with free drainage of the uncured emulsion. The method for determining emulsion content published by Chevron USA Inc. (10) appears workable and, at the moment, the simplest and best method. Again, however, an emulsion content that will leave a residue equivalent to the asphalt demands for a hot mix should be equalled or exceeded if possible. However, because of the large proportion of water necessary for a satisfactory emulsion, it is difficult, in many cases, to add enough emulsion to provide the desired residual asphalt without creating a drainage problem.

Another problem encountered when attempting to test cold mixes involves the measurement of emulsion (or asphalt) content. Although the hot extraction method (Test Method No. Calif. 310 - Figure 51) had been used for this purpose,

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problems were often encountered. These problems generally appeared to be associated with the large quantity of water in the emulsion system.

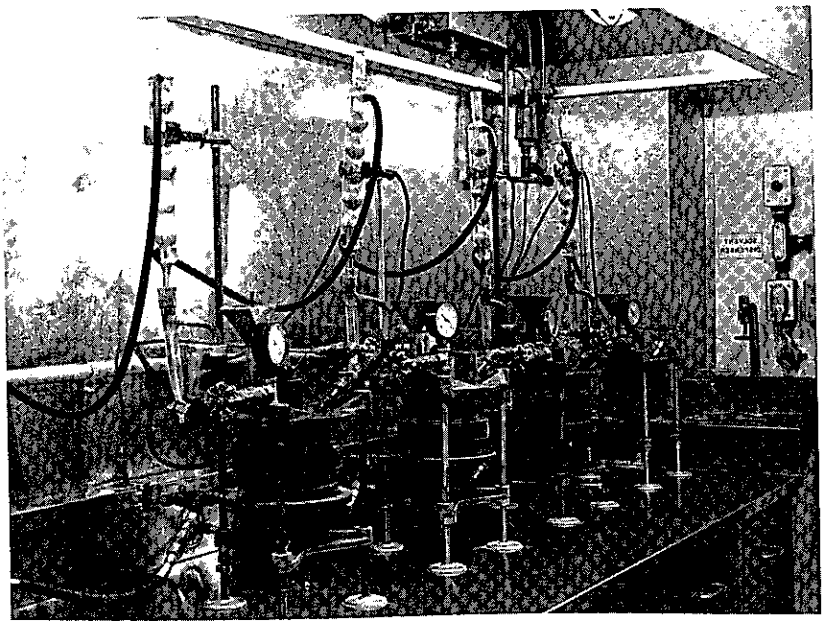

Figure 51

The temperatures which would provide refluxing action with regular asphaltic mixtures were often too high for emulsion mixtures. The result was a rapid generation of vapor in the extraction thimble causing a "belching" of water and solvent. To avoid such a condition, the extraction units had to be closely monitored to avoid "boil overs" or belching. The test results were frequently erratic and time required to perform the test was increased.

Consequently, some laboratory work was completed to determine whether pre-drying an emulsion mixture in an oven could permit the use of higher refluxing temperatures. This would expedite the refluxing operation as well as permit personnel freedom, during refluxing, for other work.

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Both open graded (3/8" [9.5 mm] max) and dense graded (1/2" [12.7 mm] max) mixes were tested. With these gradings, 6.0% CMS-2 and 6.3% CSS-1, respectively, were used. The amount of emulsion used was based on CKE data for conventional AC mixes containing these aggregates. The residual quantity indicated by the CKE test (Test Method No. Calif. 313) was considered to be the minimum desired so the emulsion content was adjusted accordingly. This may or may not have been exactly optimum; however, it is felt that it was close and could be considered representative of typical emulsion mixtures. Each emulsion used was tested for binder content and the amount of asphalt, water and cutter stock recorded. A given amount of premix water and emulsion was used in each mixture and, from the tests on the emulsion, the "actual" asphalt residue for each sample was determined by calculation using known values for pre-mix moisture, emulsion moisture, and amount of cutter stock in the emulsion. The asphalt content as determined by extraction was then compared to this "actual" quantity. All samples were prepared in duplicate.

The curing times were arbitrarily selected in order to be certain of obtaining some curing effect. It was recognized that lesser curing times may also be effective; however, this would only apply to mixtures cured at 230°F (110°C) and/or with emulsions containing no cutter stock.

The test results for the samples containing CMS-2 extracted without an oven cure and after curing at 140°F (60°C) for up to 15 hours both showed that the measured asphalt content exceeded the actual asphalt content (Figures 53 and 54). A possible explanation for this is the presence of 6.5% cutter stock in this emulsion which is flushed through the filter with the asphalt and cannot, therefore, be deducted as in the case of water which is distilled, trapped, recorded and

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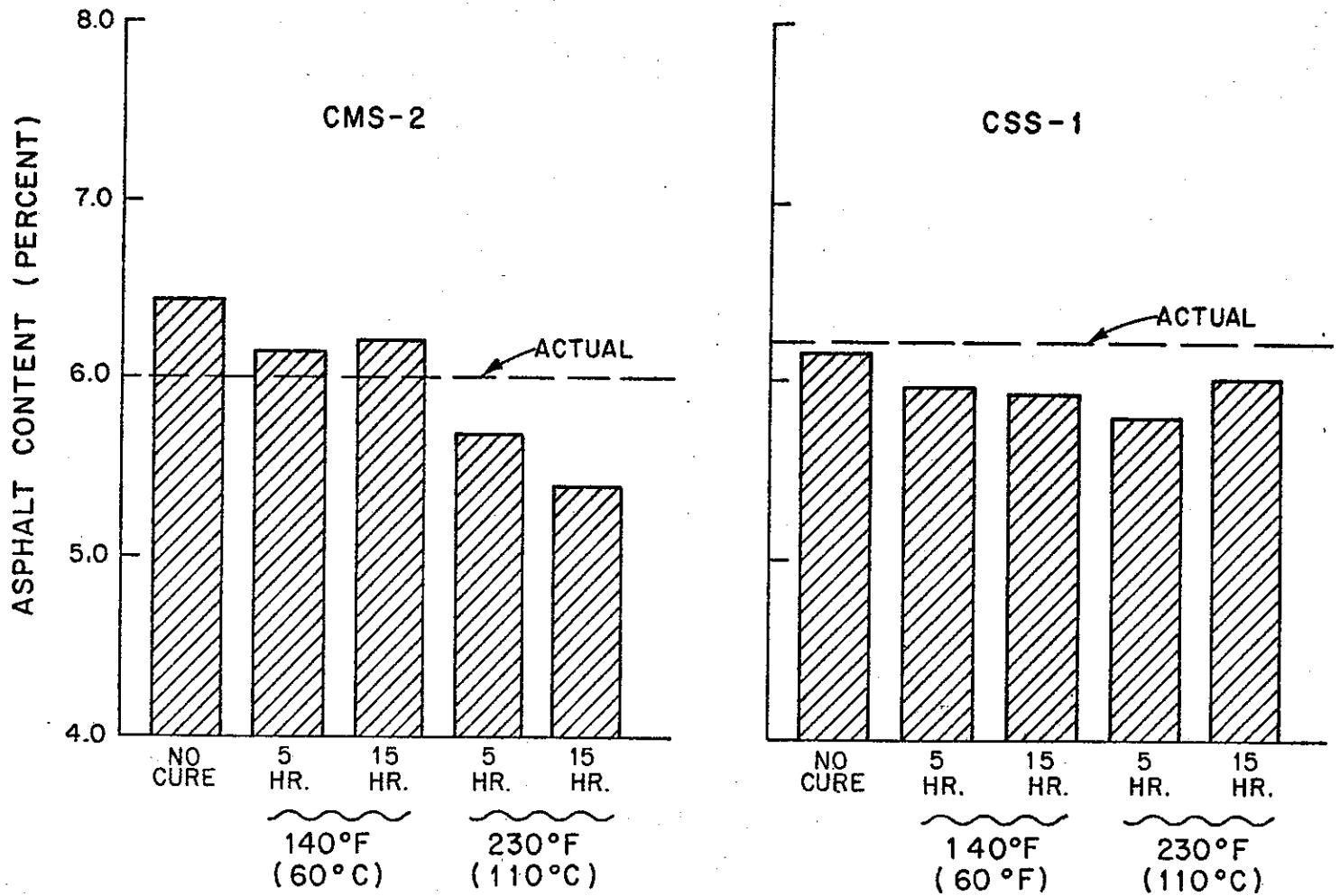
EMULSION EXTRACTION

(CALIF. TEST METHOD 310)

FIGURE 52



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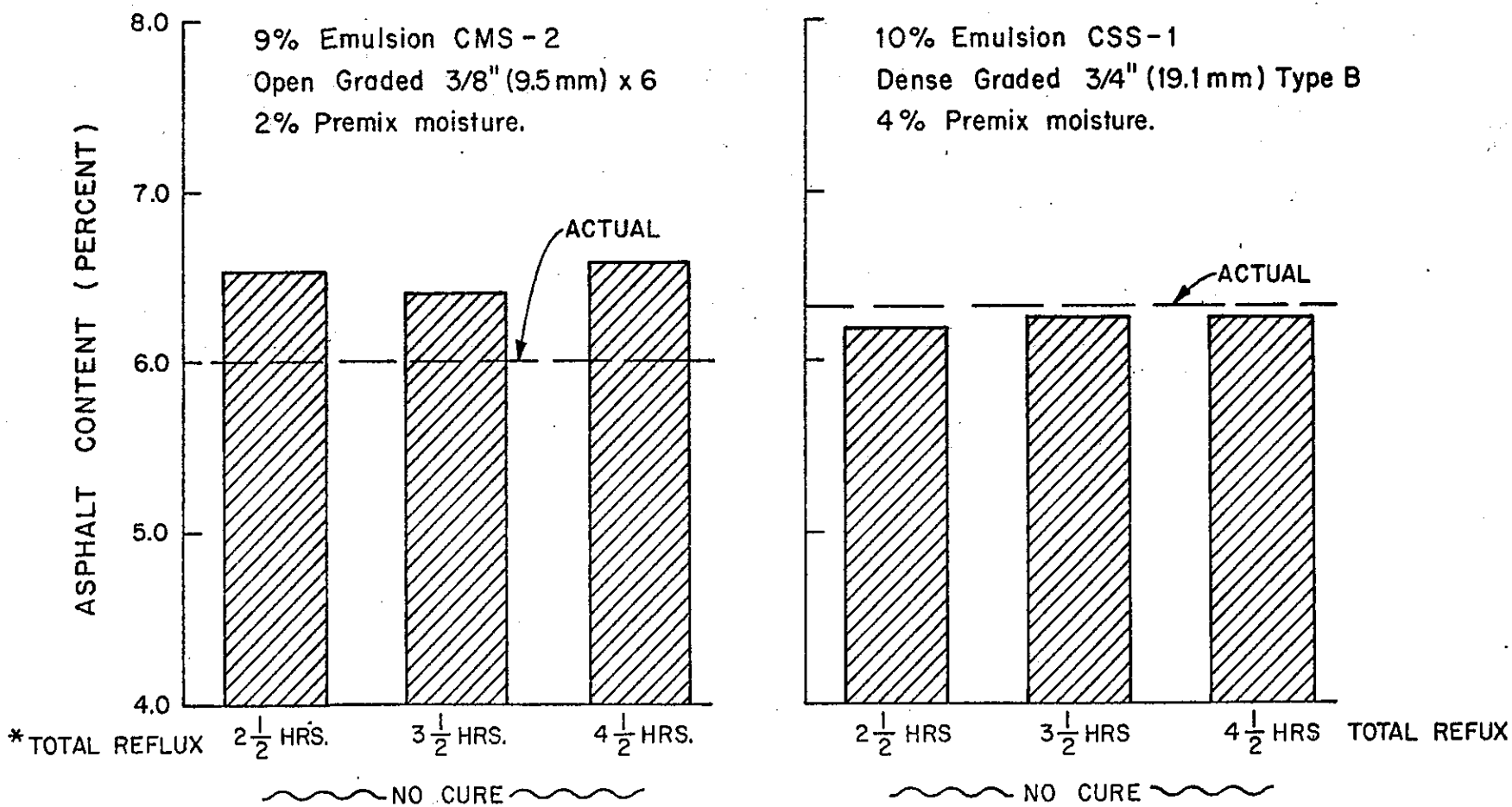
EMULSION EXTRACTION

(CALIF. TEST METHOD 310)

FIGURE 53



*Reflux Time = Starts with application of heat and stops when constant moisture quantity is observed.

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deducted. The entire amount of cutter stock was present when an extraction was made without oven cure, and after 15 hours at 140°F (60°C) a sufficient quantity was apparently still present to cause erroneous results. Extending the refluxing time for as long as 4-1/2 hours had no effect on the test results.

Curing the samples containing the CMS-2 emulsion in an oven at 230°F (110°C) for either 5 or 15 hours resulted in measured asphalt contents less than "actual". In this instance, it was felt that the curing may have been sufficient to remove all the cutter stock. Extraction of mixes containing paving asphalt has generally resulted in about a 0.3% differential lag between actual and measured asphalt content. Thus the theoretical asphalt content indicated with emulsion mixtures cured at 230°F (110°C) corresponds quite well with the accuracy expected of a conventional hot mix containing paving grades of asphalt.

All the uncured samples containing the CMS-2 required the constant attention of the technician during refluxing to prevent boil-overs. All the oven cured specimens required minimal attention and about the same refluxing time as that required for conventional mixtures.

The measured asphalt contents for the oven-cured samples containing CSS-1 emulsion were slightly less than those for the uncured samples. As was the case with the mixes containing CMS-2 emulsion and cured at 230°F (110°C), the differential between actual and measured asphalt contents is close to what is expected of conventional mixtures containing paving asphalt.

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Again, all the uncured samples required the constant attention of the technician during refluxing to prevent boil-overs. All the oven cured specimens required minimal attention and the time for refluxing was again comparable to that required for conventional mixtures.

These results indicate that emulsion mixtures containing a cutter stock in the emulsion will be difficult to extract with Test Method No. Calif. 310 unless oven dried for 5 hours at 230°F (110°C) prior to refluxing. Emulsion mixtures without cutter stock can be accurately extracted with or without preliminary oven curing. However, without this oven cure, considerable time and attention will be required on the part of the technician. Thus hot extraction testing of both mixes after curing the mix at 230°F (110°C) for 5 hours appears to be the best procedure of those examined to adopt.

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V. REFERENCES

1. Scrimsher, T., Johnson, M. H., and Sherman, G. B., "Cold Asphalt Concrete Overlay," California DOT Report CA-HY-MR-3542-1-72-48, December 1972.

2. "Standard Specifications," State of California, Department of Public Works, January 1971.

3. "Highway Design Manual of Instructions," State of California, Department of Transportation.

4. Mann, G. W. and Svetich, Ralph R., "Skid Tester Correlatin Study," State of California, Materials and Research Department, Research Report 633126-7, January 1972.

5. Richardson, E. S. and Liddle, W. A., "Experience in the Pacific Northwest With Open Graded Emulsified Asphalt Pavements," FHWA Implementation Package 74-3, July 1974.

6. "Mix Design Methods for Liquid Asphalt Mixtures," The Asphalt Institute publication MISC-74-2, February 1974.

7. Schmidt, R. J., "A Practical Method for Measuring the Resilient Modulus of Asphalt Treated Mixes," Highway Research Record No. 404, 1972, pp 22-32.

8. "Bitumuls Base Treatment Manual," Chevron Asphalt Company, 1967.

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9. Scrimsher, T., Mann, G. W., Sherman, G. B., and Johnson, M, H., "Selection of Optimum Binder Content for Bituminous Treated Bases," California Department of Transportation Report No. CA-HY-MR-3378-1-73-03, January 1973.

10. Coyne, L. D., "Emulsion Stabilization Mix Design," Chevron Asphalt Company, Technical Paper Number 172, January 1976.

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