Evaluation of Deterioration on US 20 in Webster County

Final Report for MLR-91-1

January 1991

Highway Division

Iowa Department of Transportation

Evaluation of Deterioration on US 20 in Webster County

Final Report
for
Iowa DOT Project MLR-91-1

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January 1991

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Disclaimer

ABSTRACT

Ten miles of U.S. Highway 20 in Webster County began to show deterioration in 1990. Any deterioration was unexpected, since the road was just constructed in 1986 and 1987. The deterioration looked much like the staining and cracking of D-cracking. Cracking was found on 391 joints throughout the 10 mile four lane divided highway.

Evaluation of cores from the project reveal low air contents at those locations where cracking is occurring. The cause of the low air contents can only be speculated on. A possible cause may be the vibration from the paver coupled with the additional vibration at the joints. Other projects constructed in 1986 and 1987 with the same equipment show no signs of distress.

ACKNOWLEDGEMENT

The report was compiled with the help of the Jefferson Construction Residency, the District #1 Materials Office, and the PC Engineer and Geologists in Central Materials. The Fred Carlson Company was also very cooperative providing information about the construction.

INTRODUCTION

Minor deterioration of U.S. Highway 20 in Webster County was noticed in May, 1990. Any deterioration was unexpected, since the road was just constructed in 1986 and 1987. The appearance of several joints was similar to the staining and cracking associated with D-cracking, Figure 1. A class 3 durability stone not associated with early D-cracking was used on the project.

The cracking was observed on several joints throughout a 10 mile length between the interchange at highway 17 north and the interchange at highway 169. This investigation was undertaken to determine the extent and cause for the deterioration.

PROJECT INFORMATION

The deterioration extends over four projects on U.S. Highway 20:

F-520-4(30)--20-40 (Hamilton Co.)

F-520-3(16)--20-94 (Webster Co.)

F-520-3(12)--20-94 (Webster Co.)

F-520-3(18)--20-94 (Webster Co.)

The Fred Carlson Co. Inc. constructed this segment of four lane divided highway in 1986 and 1987. A C-3 mix with and without fly ash and with and without water reducer was used. The section is 9 inches of dowelled concrete over 4 inches of lean concrete base.

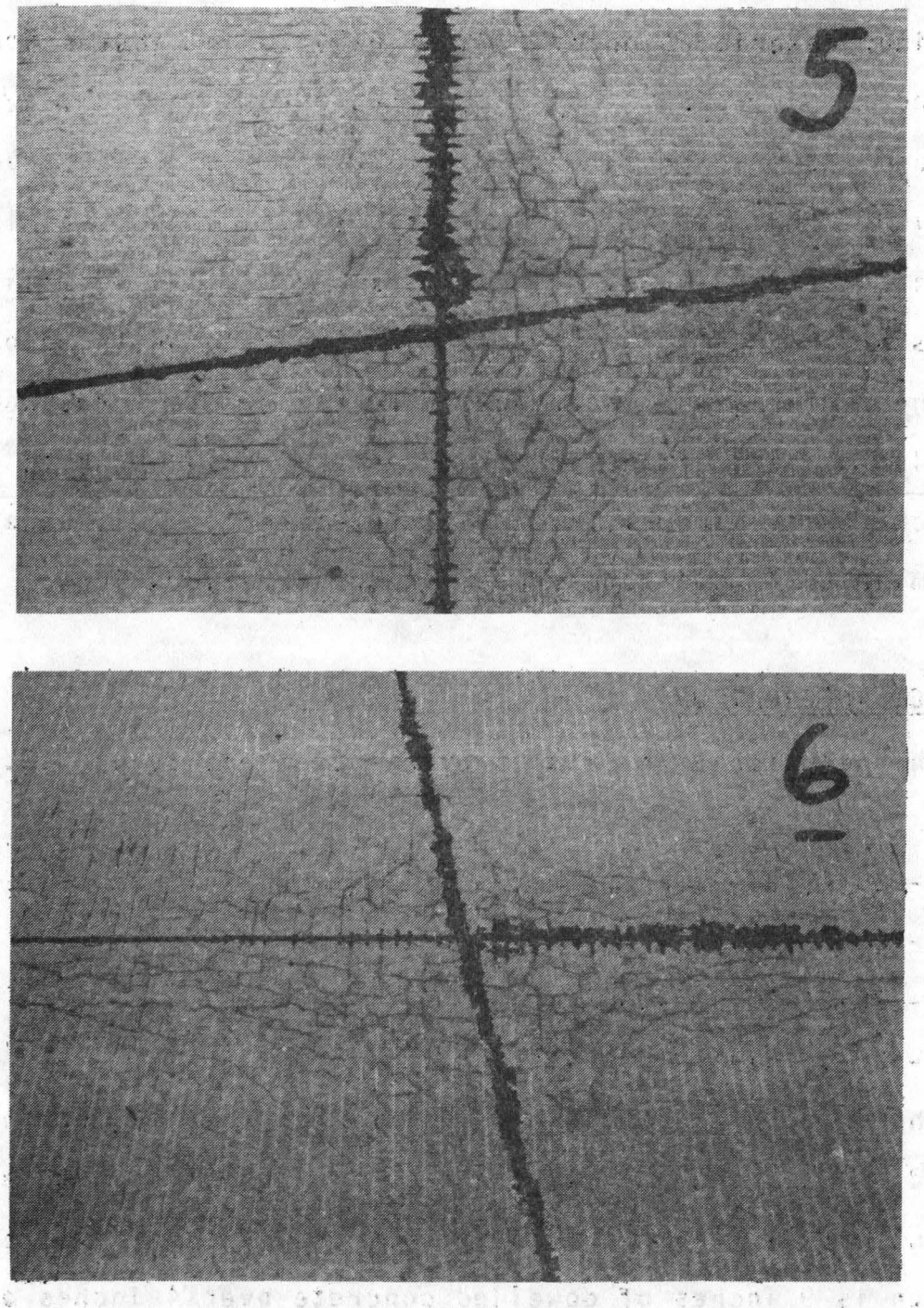


Figure 1
Joint Deterioration on Pavement Section Placed 4-27-87
Sta. 2065 to Sta. 2087 WB

The materials used were:

Cement-Lehigh and Northwestern

Fly Ash - Port Neal 4, Ottumwa, and Nebraska City

Coarse Aggregate - Fort Dodge Mine (A94002)

Fine Aggregate - Yates (A94502) and Croft (A94522)

Air Entraining Admixture - CSC Air

Water Reducer - Plastocrete 161

EVALUATION

The evaluation consisted of mapping the deterioration, reviewing the project records, and analyzing cores from the pavement.

Mapping the Deterioration

The entire length of the four projects was surveyed for cracking. Appendix A is the layout of the project showing the locations of distress. Photographs and a detailed layout were obtained and are on file in the Materials Office. Table 1 is a summary of the survey. The Mix No. explanation is in Appendix A. The condition rating is the average rating of the joints in the section showing deterioration. The rating is as follows:

1. Minor - 1 to 3 fine cracks visible.
2. Moderate - 3 to 6 fine cracks visible.
3. Severe - Extensive fine cracking visible.

Four sections paved 6/10/86, 6/16/86, 4/27/87, and 5/7/87 had over 20% of the joints showing cracking. April 27, 1987 was the worst section with 61 percent of the joints showing cracking. Deterioration was found on 391 joints.

Table 1. Condition Survey - 1986 Paving

Date Poured	Mix No.	No. of Joints Cracked	% Cracked	Average Condition Rating	Length (Ft.)
5-19	3	2	--	1.5	1300
5-20	3	0	0	0	3000
5-21	3	21	14	1.5	2900
5-22	3	0	0	0	3800
5-23	3	0	0	0	3400
5-30	3	2	2	1.5	2300
5-31	3	0	0	0	1100
6-2	3	3	1	2.0	4300
6-3	3	16	7	1.4	4300
6-4	3	1	1	1.0	1400
6-10	3	35	32	1.8	2200
6-12	3	12	9	1.2	2800
6-13	3	6	4	1.8	3000
6-16	3	62	41	2.1	3200
6-17	3	4	2	1.5	4200
6-18	3	13	6	1.6	4500
6-19	4	31	13	1.6	4400
6-20	4	1	--	2.0	2500
10-20	2	0	0	0	2500
10-21	2	0	0	0	4100
10-22	2	0	0	0	2200
10-23	2	0	0	0	2500
11-6	2	0	0	0	2000
11-7	2	0	0	0	3100
		Condition Survey - 1987 Paving			
4-23	1	4	2	1.2	3100
4-24	1	0	0	0	800
4-27	1	67	61	1.9	2200
4-28	1	34	18	1.9	3400
4-29	1	6	3	1.3	3400
4-30	1	0	0	0	1200
5-4	1	1	--	2.0	3500
5-5	1	2	1	1.0	4100
5-6	1	10	6	1.5	4100
5-7	1	47	21	1.7	4500
5-8	1	5	2	1.4	4400
5-11	5	6	3	1.7	4300
5-12	6	0	0	0	4000
5-13	6	0	0	0	2600

Review of Project Records

Laboratory test reports for the cement, fly ash, mix water, admixtures, and aggregates were reviewed. All test results were consistant with expectations for the materials and all materials met specifications.

The daily plant reports were reviewed for water to cement ratios, gradation, slump, air content, weather conditions, and placement information. Nothing on the daily plant records suggested a problem. For the four worst areas of paving, the water to cement ratio was 0.433 to 0.457, the air content was 5.5% to 6.8%, and the slump was 1 to 2 inches. The mix information for the four worst days is in Table 2.

The daily diaries from the projects were studied. The entries for April 27, 1987 are the only entries with unusual problems noted (Appendix B). The paving problem was evident at the beginning of the day. One diary says the tamping bars were lowered and paving continued. The first 300 feet of pavement was bad enough to be removed and replaced. More of the section was damaged, but it was not considered bad enough to remove.

Core Evaluation

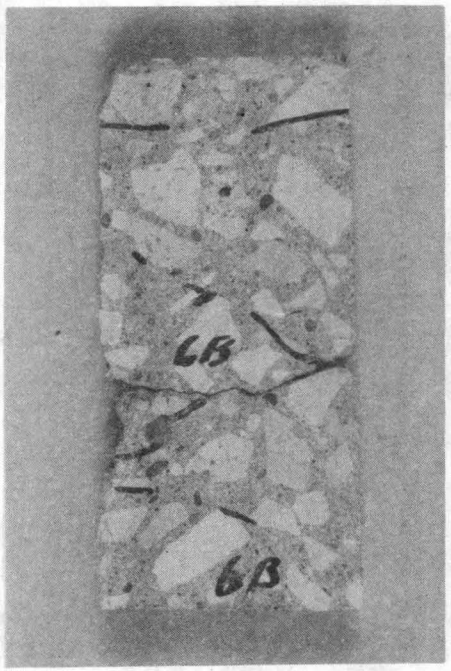
The cores were initially examined visually. Figure 2 shows those cores with cracking. The cracks have been highlighted to show the extent and pattern. A 50 power optical microscope was used to identify most of the cracking from the sawed sections.

Table 2. Information from Daily Plant Reports for Problem Sections

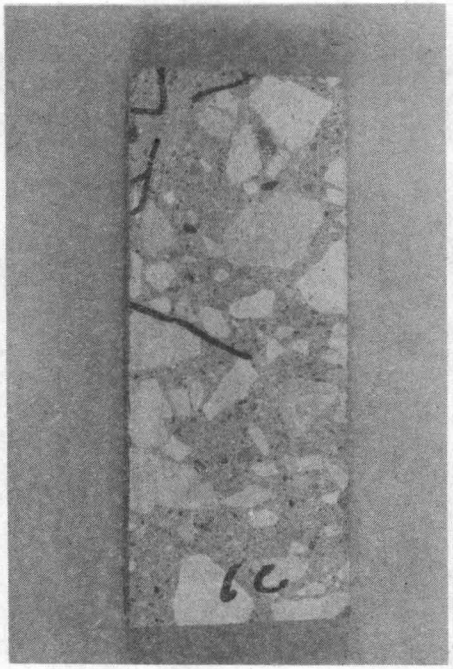
Combined Gradation

Date	6-10-86	6-16-86	4-27-87	5-7-87
Sieve		% Passing		
1-1/2	100	100	100	100
1	91	98	96	98
3/4	70	79	77	80
1/2	57	64	64	64
3/8	49	53	53	53
4	44	44	44	44
8	39	40	38	38
16	32	33	31	31
30	15	17	18	18
50	5.1	6.1	3.4	3.0
100	1.2	1.2	0.8	0.8
200	0.3	0.9	0.7	0.5
W/C	0.433	0.457	0.440	0.449
% of Joints Showing Deterioration	32	41	61	21
Mix No.	3	3	1	1
Max. AirTemp. ^{o} F.	87	80	86	83
Condition	Windy	Windy	Windy	Windy

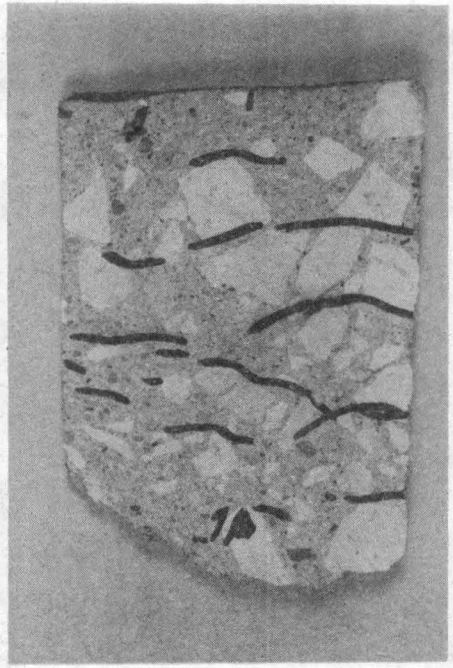
Figure 2
Vertical Sawed Sections From Cores Showing Distress
(Cracks have been highlighted for better visibility)



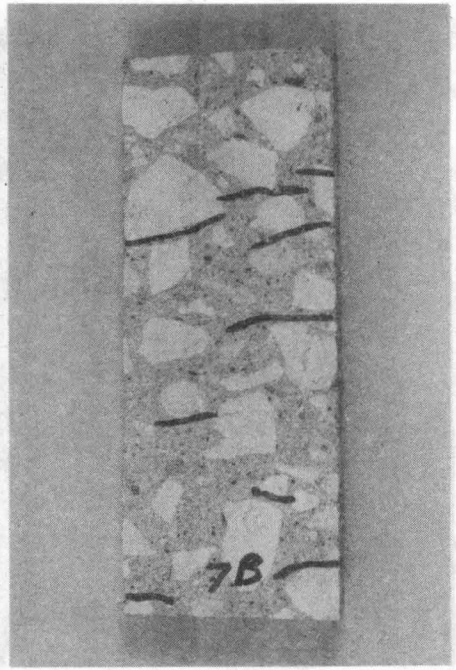
Sta. 2271+40 EB
Taken at outside wheel path next
to transverse joint



Sta. 2271+35 EB
Taken at outside wheel path
at mid panel

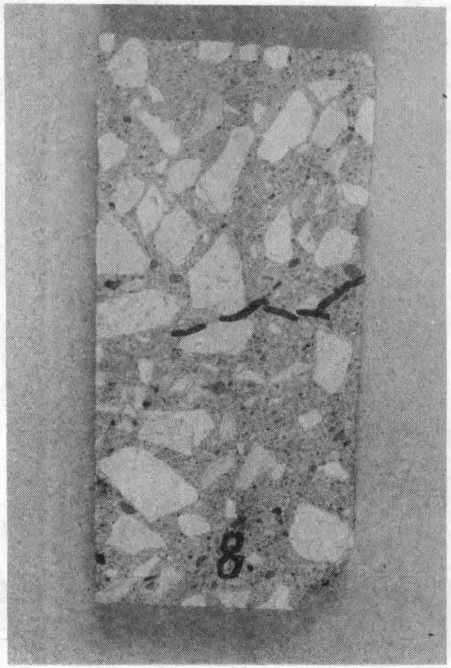


Sta. 2271+80 EB
Taken at outside wheel path next
to transverse joint



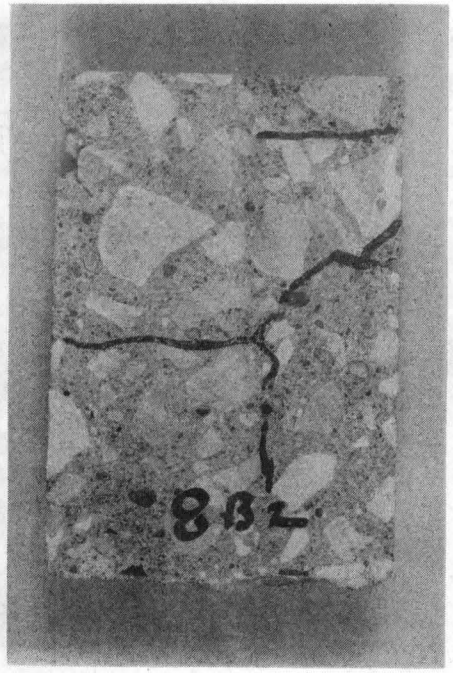
Sta. 2271+80 EB
Taken at outside wheel path next
to transverse joint

Figure 2 Cont.



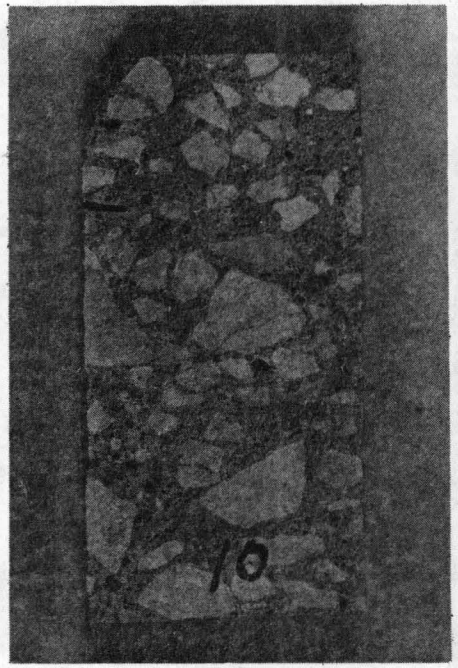
Sta. 2271+90 EB
Taken at outside wheel path
at mid panel

Sta. 2272+00 EB
Taken at outside wheel path next
to transverse joint

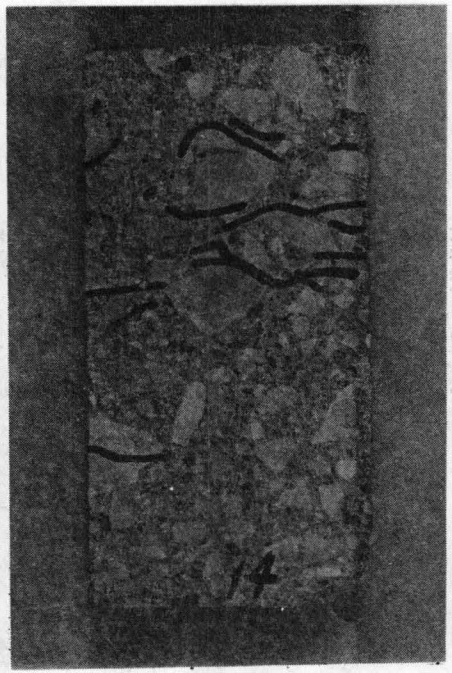


Sta. 2272+00 EB
Taken at outside wheel path next
to transverse joint

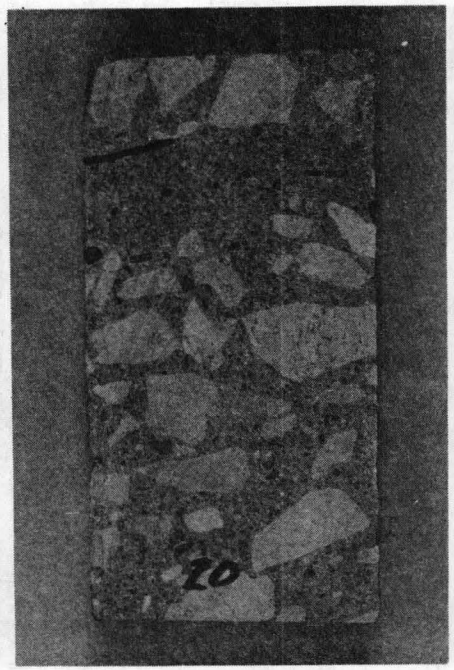
Figure 2 Cont.



Sta. 2300+10 EB
Taken at outside wheel track
at mid panel



Sta. 2105+05 WB
Taken near intersection of
transverse and longitudinal joints



Sta. 27+20 WB
Taken near intersection of
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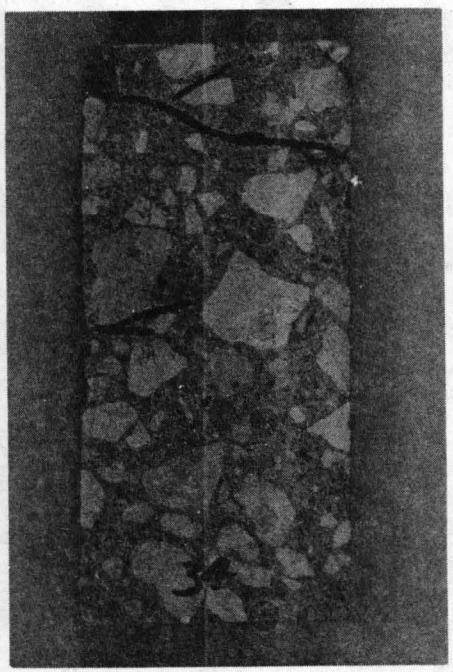


Sta. 2280+ EB
Taken at intersection of
transverse and longitudinal joints

The cores were also checked for air content, sulfur content, and chloride content. Table 3 is the results of the air content testing. The air content of several cores was lower than would be expected for air entrained concrete. Eight of the twelve cores with air contents below 3 percent showed visual cracks. Core 14 showed cracks but the air content was 4.1 percent. Further examination of the cores revealed the appearance of a lower air content toward the top of core than toward the bottom. Core 6C was examined by the linear traverse an inch from the surface and an inch from the bottom. The air content at the top is 1.1% and at the bottom 4.4%. Several of the other cores with low air appeared to have the same type of air distribution as Core 6C. However, no further linear traverse testing was performed on top or bottom sections. Air testing on project cores in 1987 did not show low air contents. The areas of low air contents are mostly limited to some joints.

X-ray flourescence was performed on cement paste from 8 of the cores. Table 4 contains the results. No unusual amounts of either chloride or sulfur were found.

DISCUSSION

The cracking is widespread across the four projects. Cracking was found on mainline placed on 24 different days during a 2-year period. The common mix material for those sections is the coarse aggregate only. Two cements, three fly ashes, two sands, and two mix types were used in those sections showing cracking. The section with the worst cracking is the section with paving and paver problems.

Table 3. Air Content Testing on Cores

Core Number	Location			% Air in Hardened Conc. High Pressure	% Air in Hardened Conc. Linear Transverse
1	2076+20	WB	Joint	4.5	
2	2075+90	WB	Mid Panel	5.1	
3	2040+04	WB	Joint	6.1	5.2
4	847+00	WB	Joint	5.6	
5	847+10	WB	Mid Panel	5.7	
* 6B	2271+40	EB	Joint	2.5	
* 6C	2271+35	EB	Mid Panel	2.2	1.1 Top/4.4 Bottom
* 7B	2271+80	EB	Joint	2.4	
* 8	2271+90	EB	Mid Panel	2.9	
* 8B2	2272+00	EB	Joint	2.1	3.3
9B	2300+00	EB	Joint	3.7	
*10	2300+10	EB	Mid Panel	2.7	
11	849+	WB	Mid Panel	6.1	
12	2013+	WB	Joint	3.6	
13	2102+05	WB	Mid Panel	5.5	
14	2105+05	WB	Joint	4.1	
15	2145+	WB	Mid Panel	6.2	5.4
16	2145+	WB	Joint	4.0	
*17	5+	WB	Mid Panel	2.8	
*18	5+	WB	Joint	2.5	
19	27+20	WB	Mid Panel	4.5	
*20	27+20	WB	Joint	2.1	
*21	36+40	WB	Mid Panel	1.9	
22B	36+40	WB	Joint	4.1	
23	53+	WB	Mid Panel	5.3	
24	53+	WB	Joint	3.5	
25	835+	EB	Mid Panel	5.2	
26	835+	EB	Joint	5.5	
27	2083+	EB	Mid Panel	4.6	
28	2083+	EB	Joint	5.3	
29	2093+80	EB	Mid Panel	5.4	
30	2093+80	EB	Joint	4.7	
31	2097+	EB	Mid Panel	5.7	
32	2097+	EB	Joint	5.3	
33	2280+	EB	Mid Panel	3.5	
*34	2280+	EB	Joint	2.8	
35	2284+	EB	Mid Panel	4.6	
36	2284+	EB	Joint	3.1	
37	2289+	EB	Mid Panel	4.7	
*38	2289+	EB	Joint	2.4	

* Hardened Air Contents Below 3.0%

Table 4. Chemical Analysis of Paste Portion of Cores

Core No.	Location	Percent Mg+	Na2O	K2O	Cl	SO4
1	Near Joint	1.44	0.18	0.54	0.05	1.67
3	Near Joint	1.20	0.50	0.50	0.07	1.54
6C	Near Joint[1]	1.48	0.41	0.60	0.22	1.93
6C	Near Joint[2]	1.73	0.53	0.86	0.16	1.59
6C	Near Joint[3]	1.48	0.22	0.48	0.03	1.79
8B2	Near Joint	1.47	0.50	0.72	0.04	1.52
13	Mid Point	1.23	0.26	0.63	0.04	1.76
17	Mid Panel	1.21	0.64	0.65	0.06	1.70
27	Mid Panel	1.07	0.26	0.38	0.04	1.70
28	Near Joint	1.12	0.19	0.34	0.06	1.77

1. Sampled at a crack - near top.
2. Sampled near top away from crack.
3. Sampled from center of core.

Deterioration of the joints 3 and 4 years after construction is very unusual for any pavement in Iowa. Fort Dodge aggregate, a class 3 durability stone, would not be expected to contribute to any pavement deterioration for 20+ years.

Supplemental vibration was used at the dowel bar assemblies on this project. The CMI SF-550 paver was equipped with internal vibration. A feature of this paver is the ability to vary the progress of the paver to the concrete delivery rate. The paver reportedly rarely stopped except for breakdowns. Other projects constructed in 1986 and 1987 using this same paver and supplemental vibration do not show any sign of deterioration.

During the 1990 construction season, 4 projects were constructed using the CMI SF-550 paver, Fort Dodge Stone, and other similar materials to the Highway 20 work in 1986 and 1987. Air contents were obtained before and after the concrete went through the paver. The loss of air entrainment averaged about 1.5 percent.

The distribution of deteriorated joints suggests that the following sections may have more joints deteriorate and have the bad joints deteriorate further in the future:

Date Poured	Length	Location
5-21-86	2900'	11+06 to 39+63 W.B.
6-3-86	4400'	2185+73 to 2229+40 W.B.
6-10-86	2200'	2176+05 to 2197+74 E.B.
6-12-86	2800'	2197+74 to 2225+52 E.B.
6-13-86	3100'	2225+52 to 2256+38 E.B.
6-16-86	3000'	2256+38 to 2286+85 E.B.
6-18-86	4400'	2330+30 to 7+65 E.B.
6-19-86	4800'	7+65 to 55+28 E.B.
4-27-87	2500'	2062+54 to 2087+81 W.B.
4-28-87	3500'	2090+00 to 2124+54 W.B.
4-29-87	3200'	2124+54 to 2140+08 W.B.
5-6-87	4100'	886+40 to 927+15 E.B.
5-7-87	4600'	927+15 to 2023+95 E.B.
5-11-87	2200'	2067+67 to 2090+00 E.B.
	47700'	

CONCLUSIONS

Based on study the following conclusions can be made:

1. The primary cause of the deterioration is water related freeze-thaw damage in those areas with low air content.
2. Several secondary factors may have contributed to the deterioration: excessive frequency, amplitude, or duration of vibration during paving; a harsh, stiff mix during paving; delays in placing the concrete; and deicing salt.
3. The appearance of the cracking is similar to D-cracking although it is not related to aggregate quality. The deterioration pattern will likely be somewhat different than D-cracking because of the different pattern of low air content along the joint.
4. Future maintenance requirements will be the same as for D-cracking. The majority of joints should have sufficient air content and will not likely deteriorate in the near future.

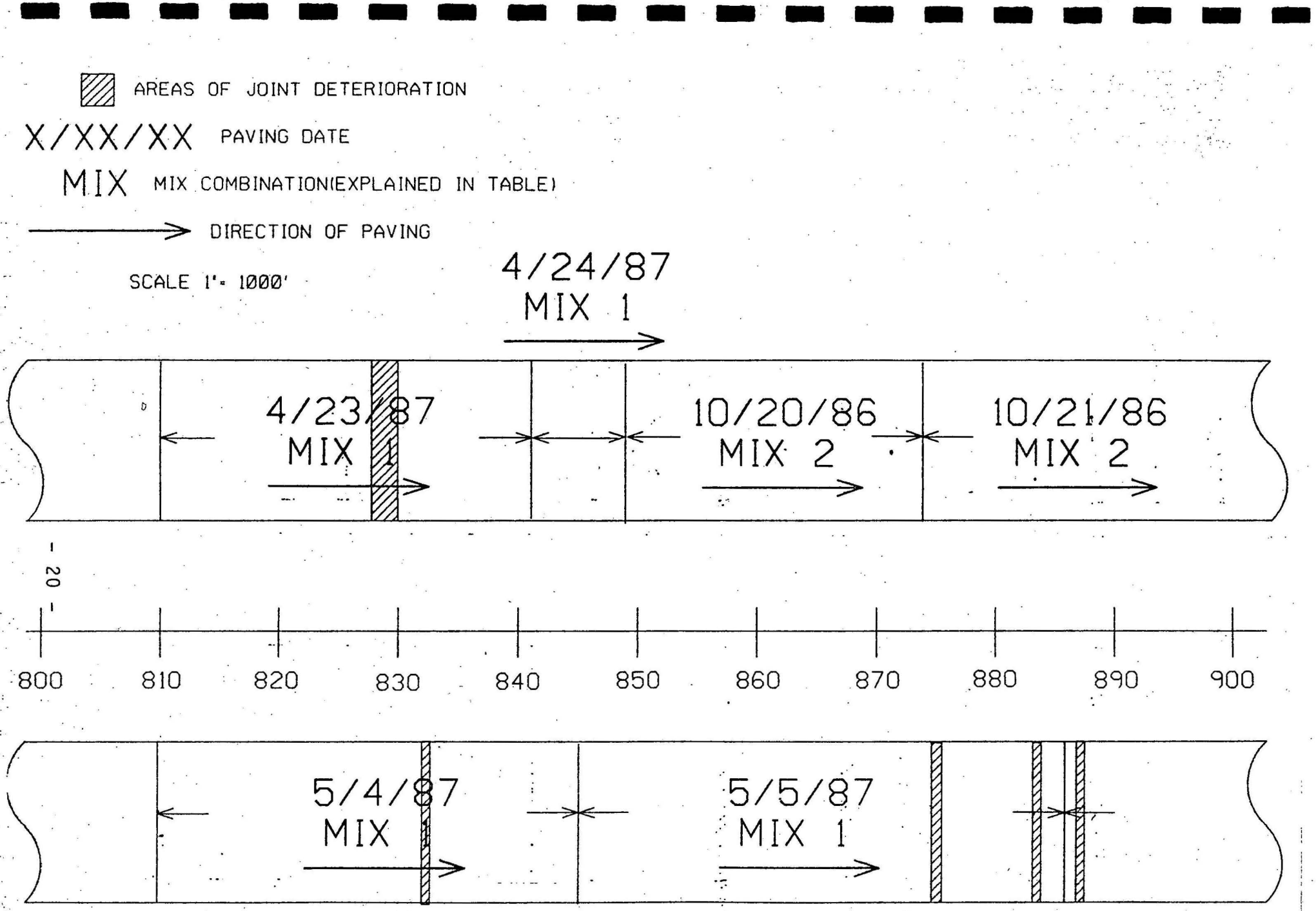
RECOMMENDATIONS

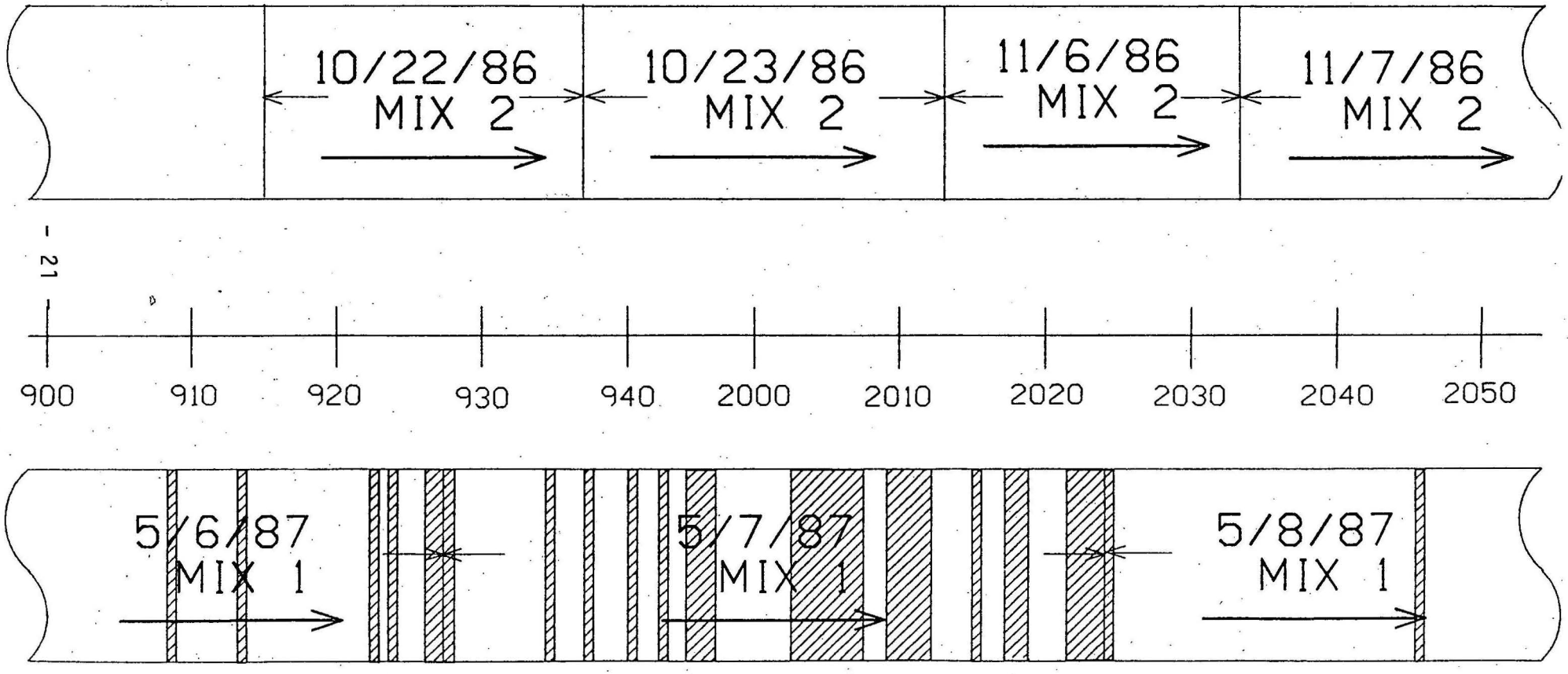
1. The Construction Office and Materials Office should evaluate the effect of paver vibration and supplemental vibration (type, frequency, amplitude, and duration) on air distribution at joints. Test equipment being evaluated in SHRP should allow for quick testing of in-place air content.
2. The condition of the 4 projects should be checked periodically for extent and pattern of the deterioration.

APPENDIX A

Mix Combinations

Mix Code	Mix	Cement	Fly Ash	Water Reducer	Sand
1	C3WRC	Lehigh	Ottumwa		Yes Croft
2	C3WR	Lehigh	None	Yes	Croft
3	C3C	Lehigh	Port Neal		No Yates
4	C3	Lehigh	None	No	Yates
5	C3WRC	Northwestern	Ottumwa & Nebraska City	Yes	Croft
6	C3WRC	Northwestern	Nebraska City & Some Port Neal	Yes	Croft


AREAS OF JOINT DETERIORATION
X/XX/XX PAVING DATE
MIX MIX COMBINATION(EXPLAINED IN TABLE)
DIRECTION OF PAVING
SCALE 1"= 1000'
4/24/87
MIX 1
4/23/87
MIX 1
10/20/86
MIX 2
10/21/86
MIX 2
- 20 -
800
810
820
830
840
850
860
870
880
890
900
5/4/87
MIX 1
5/5/87
MIX 1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10/23/86
MIX 2
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MIX 2
11/7/86
MIX 2
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910
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930
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2020
2030
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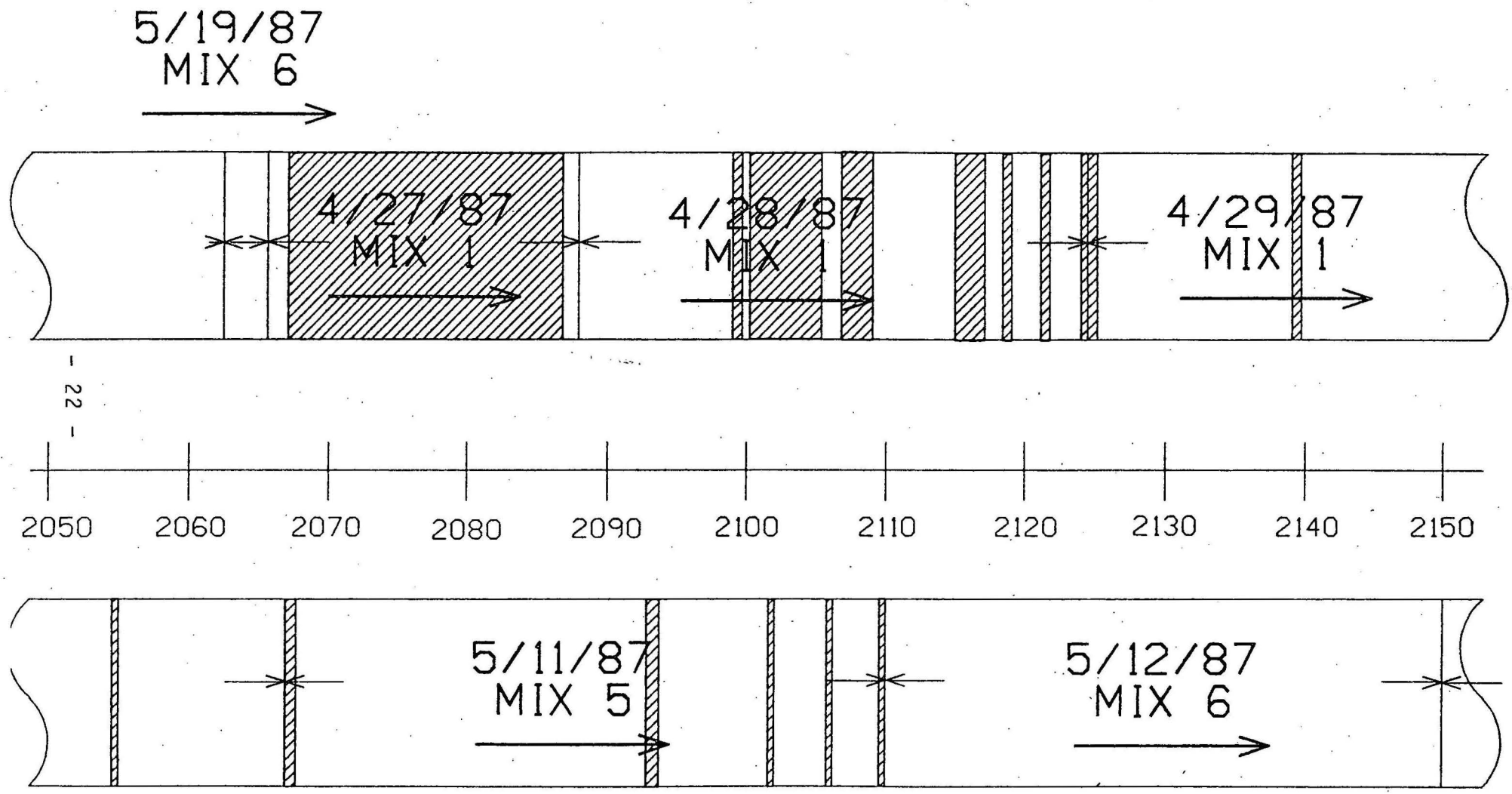
5/7/87
MIX 1
5/8/87
MIX 1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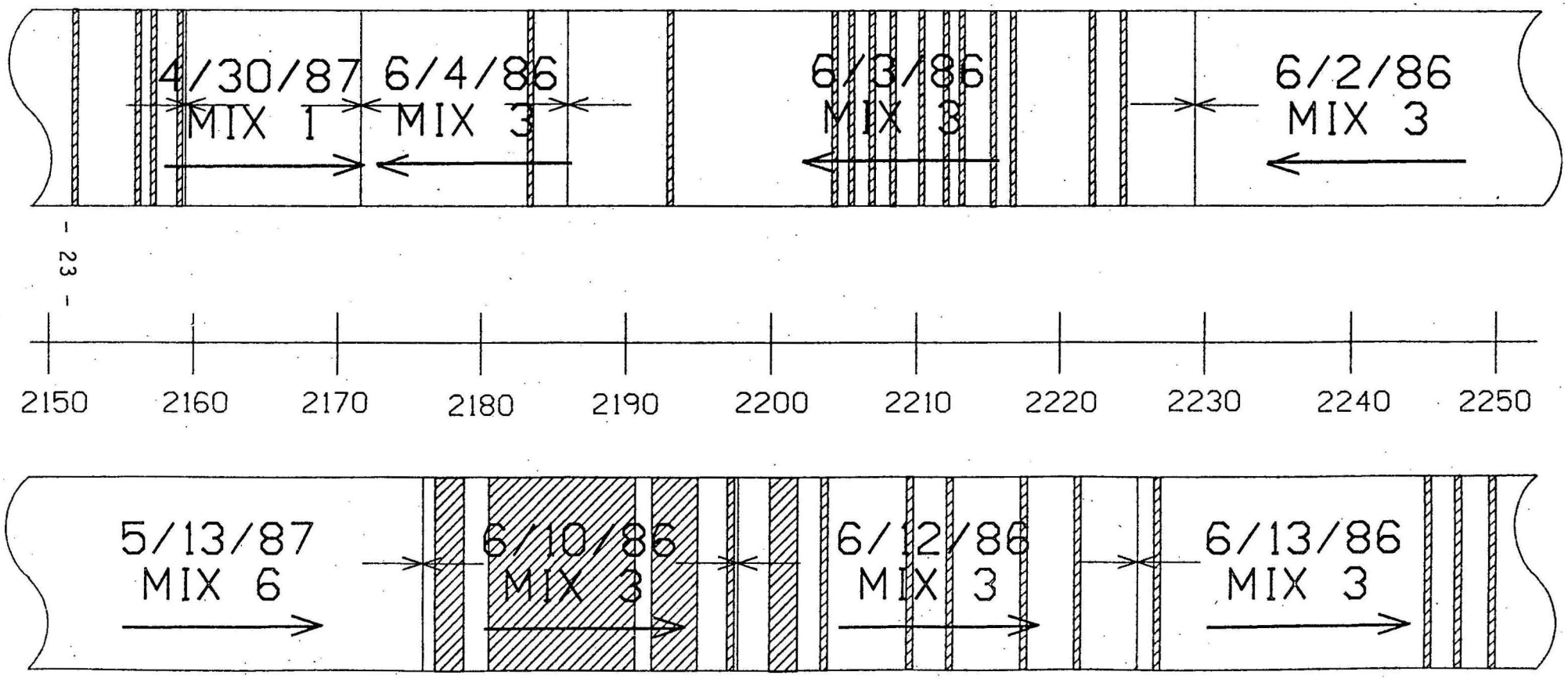
MIX 5
5/12/87
MIX 6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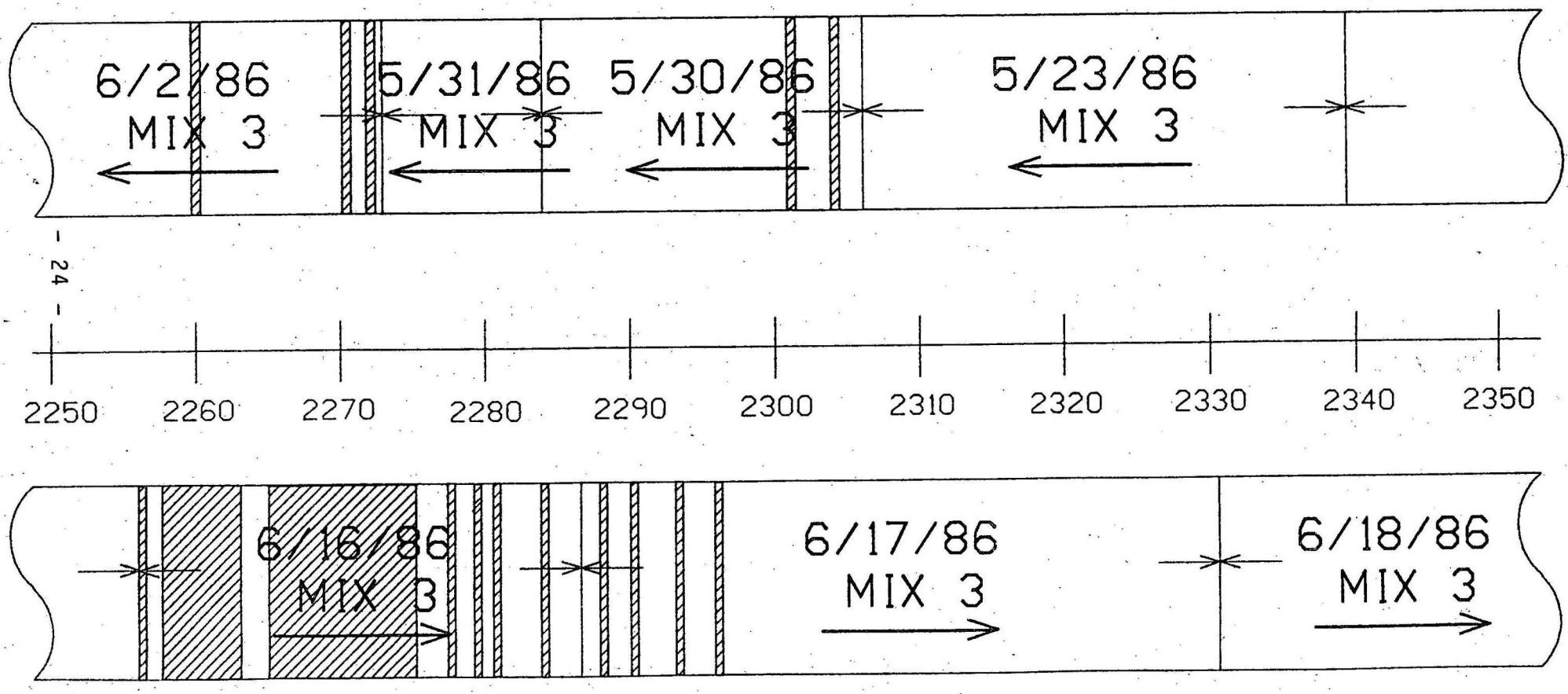
MIX 3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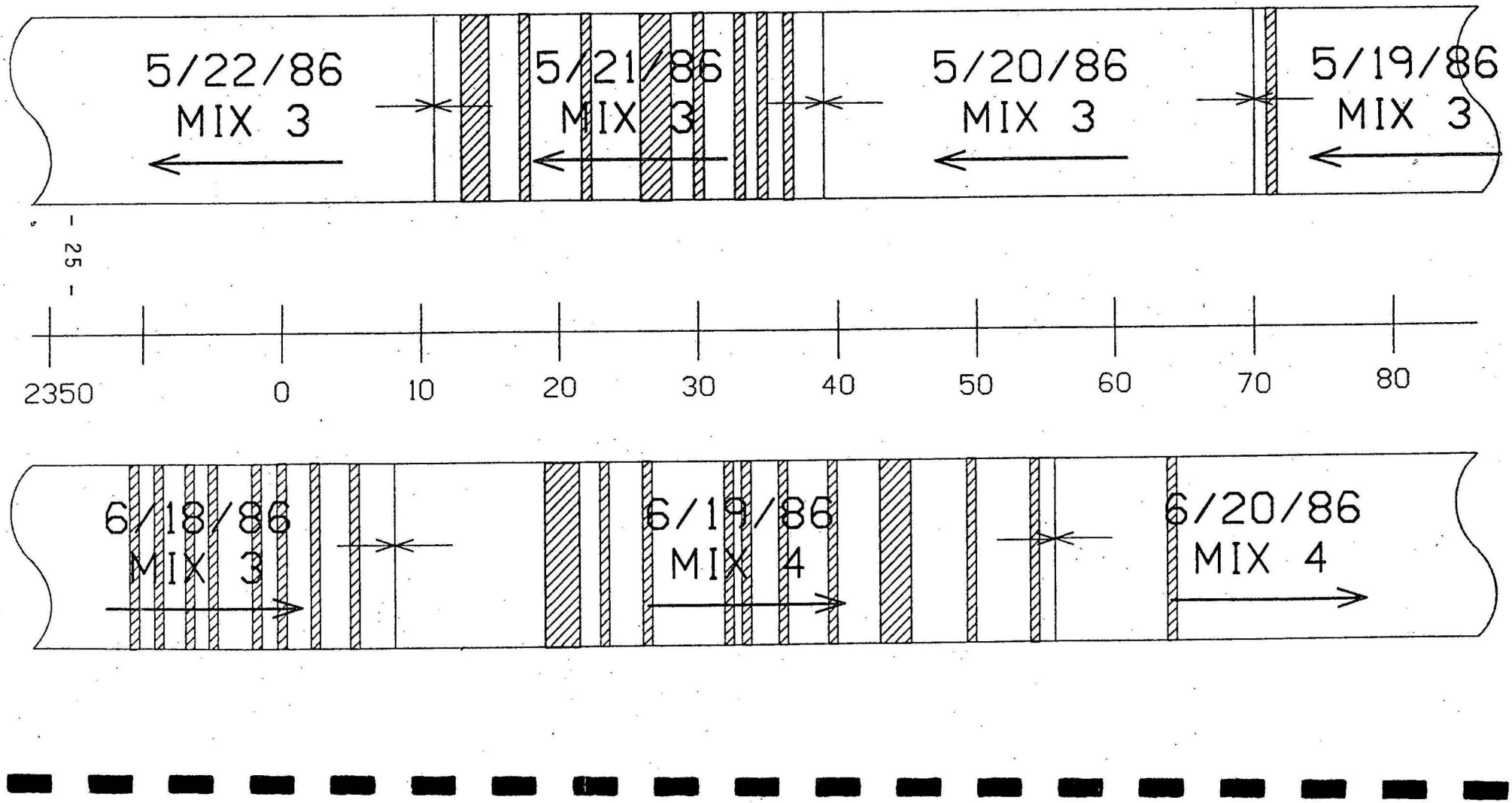
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20
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40
50
60
70
80
6/18/86
MIX 3
6/19/86
MIX 4
6/20/86
MIX 4

APPENDIX B

Date	Start	Stop	Weather	Soil	Time Lost
4-25&26-87	—	—			0
	No work Saturday & Sunday.				
4-27-87	7:00	7:00	Partly Cloudy Windy 70°	Dry	0

I Checked signs & barricades on all four project. They looked pretty good, except for snow fence on east end of Hamilton Co. project North Lane a car had run through it. Contractor put up a new fence.

Van Buskirk working on (10) project Today. Called Lane & ask him, who was going To watch Them. He said he wasn't planning on any one watching Them.

Carlson shouldering crew Blading medium & ditches on (12) & (16) projects. Also picking up rock on These projects.

Date	Start	Stop	Weather	Soil	Time Lost

Carlson laying subbase Today. Layed subbase from Sta. 810+00 To 837+62 Rt. Side. Progress fairly slow. Trost & Wuebkeron subbase. Carlson laying mainline paving from Sta. 2062+54 To Sta. 2087+81 Rt. Side. Had all Kinds of problems in first 250'±, we poured Today. I Told Bonner it didn't look very good. He Through he could fill voids in Top with epoxy or Something. Lane on project in P.M., he looked at area where we had problems. He Thought it should be Tore out. Told Lane, Trost wouldn't be here Tommorow.

Called County Engr. & Told him we were going To close Co. Road 1 mile west of P-73 Tomorrow & Close P-73 on Wednesday.

check crown in P.M. O.K
Plant shut down @ 6:00 PM
Received 29 Loads X 8 yd =
175 2 yd - 6 yd waste = 174 6 yd used

J D

4-28-87 Tuesday
Start 2087+81 @ 7:00 A.M
Stop 2090+00 @ 8:05 A.M
Progress good
Air 6.6% @ 7:05 A.M @ 2087+85
slump 1½"

J D

moved to (16) Proj.

5/5-87 Tuesday Kent & I insp.
E.B.L
Start 845+00 @ 7:00 A.M
Stop 886+40 @ 7:10 P.M.
Progress good
Air & slump = O.K.
Depth O.K.
Crown O.K.
yesterday's slwd curb & tar tue O.K.

4-29-87 Friday 8:30 To 3:30 P.M.
went accross
proj line @ 8:30 A.M.
Started 845+00 To
STA 849+10 ±
Done @ 10:15 A.M

J W

4-25 } weekend
4-26 } no work

4-27-87 Monday Hi 72° real windy 7:00 A.M ±
paving -- Start 2062+54 @ 8:20 A.M.
Stop 2087+81 @ 7:00 P.M
Had Trouble with
Slab sealing up in A.M.
R.E. Lane & John Smith here
pulled off & set Tamping
bars lower helped some
checked & Steel in
P.M. getting in as per
plan
Real windy in P.M
Also wind in A.M