396R

AGGREGATE SOURCE AND POPOUT FREQUENCY
I 94 from Stevensville to Marshall

O. L. Lindy
J. W. Sparbel

Research Laboratory Division
Office of Testing and Research
Research Project R-39 F-7(14)
Report No. R-396R

Michigan State Highway Department
John C. Mackie, Commissioner
Lansing, February 1963

PROJECT IDENTIFICATION AND LOCATION
I 94 Projects from Stevensville to Marshall
(listed in west-to-east order)

Project Code	Project Number	Project Description
A	11015, C1	From Ridge Rd northeast to St. Joseph River
B	11016, C2	From St. Joseph River northeast to southwest of Pipestone Rd
C	11016, C3	From southwest of Pipestone Rd northeast to southwest of Main St
D	11017, C3	From southwest of Main St east to Carmody Rd
E	11017, C1	From Carmody Rd northeast to east of M 140
F	11018, C1 80023, C1	From east of M 140 to west of Thomas Rd
G	80023, C2	From west of Thomas Rd east to east of Kane Rd
H	80023, C3	From east of Kane Rd east to west of M 40
I	80023, C4 80024, C3	From west of M 40 east to west of M 119
J	80024, C2	From west of M 119 east to Schussler Rd
K	80024, C1 39024, C3	From Schussler Rd east to 6th St in Texas Twp (west of Kalamazoo)
L	39024, C1	From 6th St in Texas Twp east to east of 12th St
M	39024, C2	From east of 12th St east to US 131
N	39025, C2	From US 131 east to 0.5 mi east of Climax Rd
O	13081, C2	From 0.5 mi east of Climax Rd east to west of Main St (southwest of Battle Creek)
P	13082, C3	From west of Main St east to west of Kalamazoo River
Q	13082, C4	From west of Kalamazoo River east to west of Wheatfield Rd
R	13082, C1, C2	From west of Wheatfield Rd east to 17-1/2 Mile Rd

SOURCE IDENTIFICATION AND INVENTORY NUMBERS

Code Number	Pit Name and Inventory Number	Beneficiation
1	American Aggregate (39-1)	Jigging
2	Bundy Hill (30-35)	Heavy medium separation
3	Construction Aggregates (70-9)	---
4	Grand Rapids Gravel (41-1)	---
5	Inland Lime and Stone (75-5)	---
6	Pickett & Schreur-Kellogg Pit (41-46)	---
7	A. P. Larson (3-44)	Heavy medium separation
8	Material Service-Romeo Pit (number unknown)	---
9	Material Service-Thornton, Ill. Pit (number unknown)	---
10	Nashville Gravel No. 1 (8-5)	Heavy medium separation
11	Pickett & Schreur-Shell Pit (13-30)	Soft stone disintegration
12	"Lowell Pit"; aggregate inspection reports did not give specific inventory number	---

AGGREGATE SOURCE AND POPOUT FREQUENCY
I 94 from Stevensville to Marshall

This report is a revision of Research Report R-396, published in November 1962, containing additional data with regard to beneficiation of various construction aggregates.

At the request of R. L. Greenman, Assistant Testing and Research Engineer, the Research Laboratory Division surveyed the eastbound and westbound roadways of I 94 east from Stevensville in Berrien County to west of Marshall in Calhoun County in the Spring of 1962, to determine the incidence of aggregate popouts on the concrete surfaces. The survey included a total of 151.8 lin mi of two-lane 24-ft pavement, built between 1958 and 1960.

This study, which included a complete condition survey as well as selective photography of representative areas, supplements an earlier study also requested by Mr. Greenman and described in Research Report No. 367, "Aggregate Source and Popout Frequency: I 94 from Marshall to Jackson" (1961). As in the earlier study, popout frequency has been correlated with coarse aggregate source. None of the sources or combinations of sources involved in the surveys east of Marshall (Report 367) were used west of Marshall, so that performance comparisons on the total 220.9 lin mi of I 94 must necessarily be on a project-by-project basis.

Material from two of the sources used in projects east of Marshall were beneficiated by heavy medium separation, and five sources used west of Marshall were beneficiated. Three of these last five were beneficiated by heavy medium separation, one by jigging, and one by the use of a soft stone disintegrator.

The individual projects in this new study are described in Table 1, which summarizes the frequency of popouts as classified by the system illustrated in Fig. 1. This classification differs from that used in the earlier study in that what was then termed a "light" frequency of popouts (less than 120 per 100 lin ft of pavement) is now further subdivided into two categories or degrees of frequency: "light" (25 to 120 per 100 lin ft) and "very light" (less than 25 per 100 lin ft). Thus pavements almost entirely free from popout deterioration may now be more easily distinquished from those where at least some has occurred.

In addition, an arithmetic weighting system was developed in order to rank the 18 projects involved from best to poorest in terms of popout frequency. This weighting involved assigning an index number to each frequency according to its severity, so that values of 0, 1, 2, and 3 were given to the four frequency classifications of very light, light, medium, and heavy, respectively. The weighted average for each project was then obtained by multiplying the average of the percentages of popout frequency for the eastbound plus the westbound roadways for each frequency classi-

TABLE 1
POPOUT FREQUENCY BY PROJECT

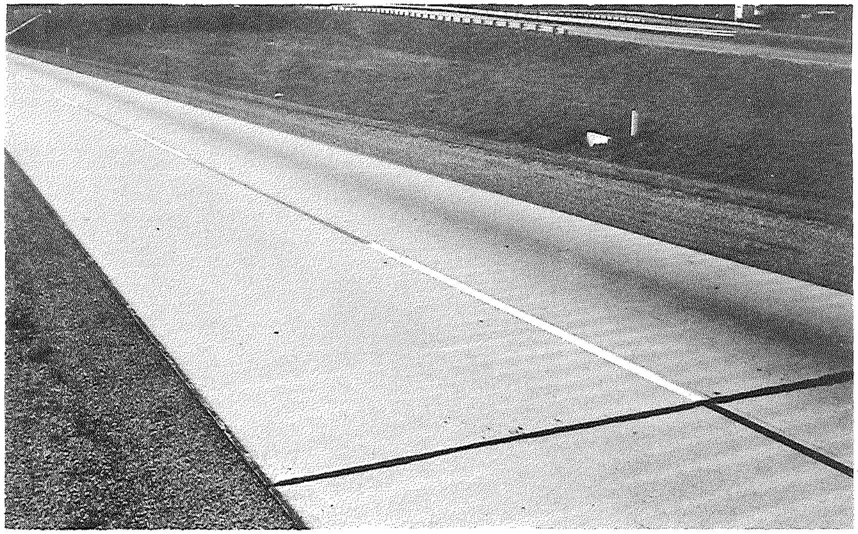
Project	Year Completed	Length, miles*	Aggregate Size and Source **	Roadway	Popout Frequency, percent of surface ***				Weighted Value	Rank, best to poorest
					Very Light (0)	Light (1)	Medium (2)	Heavy (3)		
A	1960	4.402	4A - 5	WB	100.0	- - -	- - -	- - -	0.00	1
			10A - 5	EB	100.0	- - -	- - -	- - -		
B	1960	1.716	4A - 5	WB	100.0	- - -	- - -	- - -	0.00	3
			10A - 5	EB	100.0	- - -	- - -	- - -		
C	1960	3.352	4A - 5	WB	100.0	- - -	- - -	- - -	0.00	2
			10A - 3	EB	100.0	- - -	- - -	- - -		
D	1960	3.801	4A - 5	WB	38.6	33.1	- - -	28.3	0.72	9
			10A - 3	EB	73.5	26.5	- - -	- - -		
E	1959	5.087	4A - 5	WB	- - - -	- - -	- - -	100.0	2.97	16
			10A - 3	EB	- - - -	2.8	- - -	97.2		
F	1959	4.977	4A - 5	WB	- - - -	- - -	11.0	89.0	2.73	14
			10A - 3	EB	- - - -	- - -	43.9	56.1		
G	1960	5.985	4A - 9	WB	23.1	76.9	- - -	- - -	0.71	8(a)
			10A - 7	EB	42.7	49.9	7.4	- - -		
H	1960	3.641	4A - 9	WB	79.5	20.5	- - -	- - -	0.19	5
			10A - 3	EB	82.8	17.2	- - -	- - -		
I	1960	4.097	4A - 7	WB	- - - -	38.9	61.1	- - -	1.44	10(a)
			10A - 7	EB	15.3	42.2	42.5	- - -		
J	1959	5.039	4A - 7	WB	- - - -	23.0	42.7	34.3	2.35	12
			10A - 7	EB	- - - -	16.2	8.8	75.0		
K	1959	5.074	4A - 1&8	WB	- - - -	- - -	- - -	100.0	3.00	18
			10A - 1&4	EB	- - - -	- - -	- - -	100.0		
L	1959	3.447	4A - 7	WB	- - - -	- - -	19.1	80.9	2.90	15(a)
			10A - 7	EB	- - - -	- - -	- - -	100.0		
M	1959	2.727	4A - 7	WB	- - - -	- - -	44.0	56.0	2.64	13(a)
			10A - 7	EB	- - - -	- - -	28.5	71.5		
N	1958	4.839	4A - 10	WB	- - - -	- - -	- - -	100.0	3.00	17
			10A - 1	EB	- - - -	- - -	- - -	100.0		
O	1959	6.832	4A - 10	WB	32.5	16.7	4.1	46.7	1.46	11
			10A - 1 & 10	EB	43.8	16.4	9.5	30.3		
P	1959	3.260	4A - 10 & 11	WB	- - - -	95.7	- - -	4.3	0.59	7
			10A - 1 & 11	EB	92.6	3.9	3.5	- - -		
Q	1959	1.375	4A - 10 & 11	WB	81.3	18.7	- - -	- - -	0.09	4
			10A - 11	EB	100.0	- - -	- - -	- - -		
R	1959	6.268	4A - 2, 6, 10, 11	WB	77.9	19.4	2.7	- - -	0.26	6
			10A - 2, 10 & 11	EB	80.5	12.5	7.0	- - -		
	Percentage Weighted by Mileage				35.8	16.1	9.4	38.7		

* Mileage of dual 24-ft roadway.

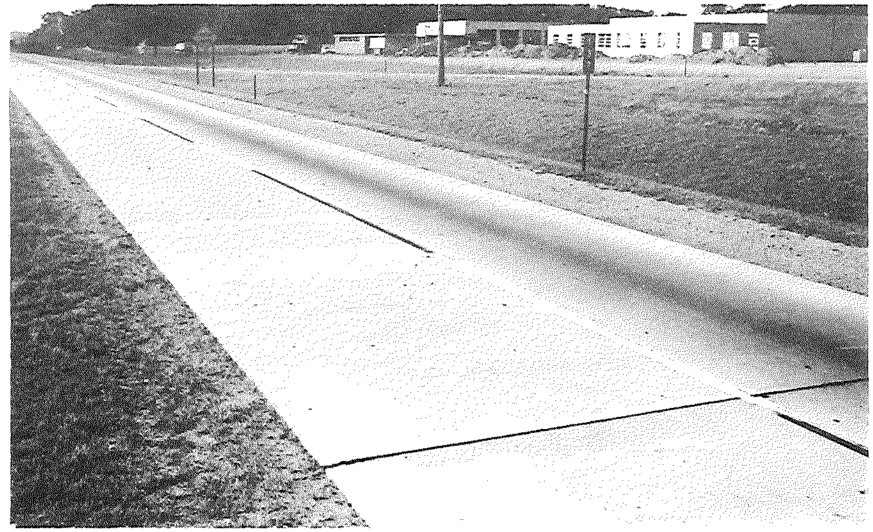
** Same source numbering as Table 2.

*** Frequency = total popouts per 100 ft of roadway
Very Light = less than 25
Light = 25 to 120
Medium = 120 to 200
Heavy = over 200

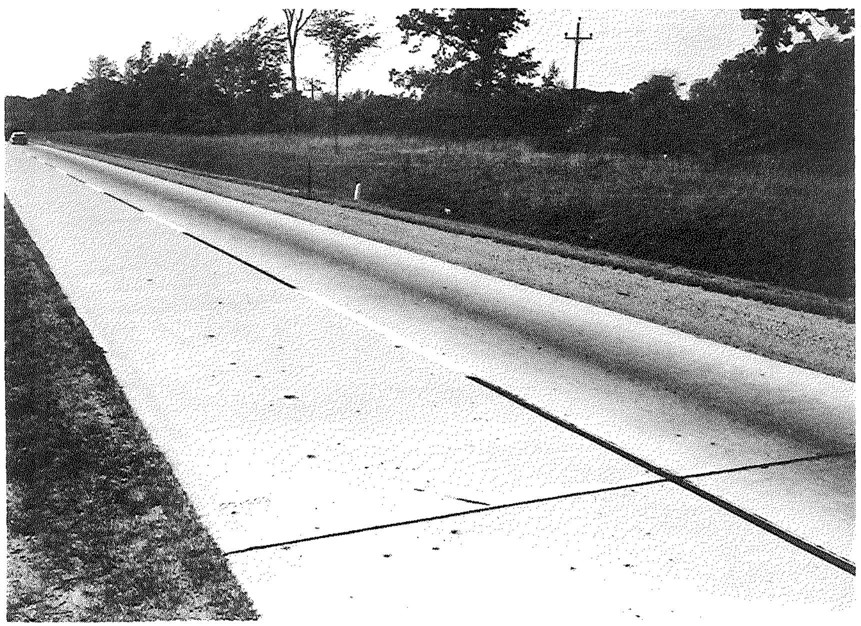
(a) Contain aggregate "sweetened" to minimize deleterious particles (see Table 3).



Very light frequency = less than 25 per 100 lin ft



Light frequency = 25 to 120 per 100 lin ft



Medium frequency = 120 to 200 per 100 lin ft

Heavy frequency = over 200 per 100 lin ft

Figure 1. Popout frequency classification.

fication by its corresponding index, totaling the results obtained, and dividing the sum by the total frequency, which is 100 percent in every case. This gave a value from 0 to 3 for each project, thus simplifying determination of average frequency and permitting ranking of projects as in Table 1. The formula used was:

$$\text{weighted average} = \frac{VL \times f_1 + L \times f_2 + M \times f_3 + H \times f_4}{\sum f}$$

where VL, L, M, and H are the index numbers for very light, light, medium, and heavy, respectively, and f_1, f_2, f_3, and f_4 are the corresponding frequencies, or average percentages. $\sum f$ is the total of the average percentages, always equalling 100. The projects were then ranked from best to poorest by these weighted values. It should be noted that the best three projects all had weighted averages of zero and the two poorest projects had values of three; in these cases the projects are listed in order of length.

The ten aggregate sources involved in this construction, used in the mixes either singly or in various combinations, are ranked in Table 2 from best to poorest performance, also in terms of total popout frequency. This ranking is based on the same formula as in Table 1 except that frequency values for Table 2 refer to the percentages listed rather than to averaged figures as used in Table 1.

As was the case for the earlier survey of projects east of Marshall, the later survey west of Marshall also showed that popouts in varying

TABLE 2
POPOUT FREQUENCY AND AGGREGATE SOURCE
(Ranked best to poorest by popout frequency)

Aggregate Source	Length, miles**	Popout Frequency, percent of surface ***				Total	Weighted Value
		Very Light	Light	Medium	Heavy		
5	12.24	100.0	0.0	0.0	0.0	100.0	0.00
10 & 11	2.75	90.7	9.3	0.0	0.0	100.0	0.09
3 & 9	7.28	81.2	18.8	0.0	0.0	100.0	0.19
2, 6, 10 & 11	12.54	79.2	16.0	4.8	0.0	100.0	0.26
1, 10, & 11	6.52	46.3	49.8	1.7	2.2	100.0	0.60
7* & 9	11.97	32.9	63.4	3.7	0.0	100.0	0.71
3 & 5	34.43	31.9	7.0	7.9	53.2	100.0	1.82
1 & 10	23.34	22.3	9.7	4.0	64.0	100.0	2.10
7*	30.62	2.1	17.3	30.9	49.7	100.0	2.28
1, 4, & 8	10.15	0.0	0.0	0.0	100.0	100.0	3.00
Percentage Weighted by Mileage		35.8	16.1	9.4	38.7		

* The only source "sweetened" (see Table 3)

** Mileage of 24-ft roadway

*** Frequency = total popouts per 100 ft of roadway;
Very Light = less than 25
Light = 25 to 120
Medium = 120 to 200
Heavy = over 200

degrees and quantities have occurred on all the projects involved. It should be noted that while three of the projects in the newer study (18 projects) are better with regard to popouts than any in the earlier study (9 projects)--with surfaces representing 18.9 lin mi of two-lane 24-ft pavement virtually free of popouts--there are also two projects in the newer study which are worse than any in the other study, with 19.8 lin mi of surface heavily marked by popouts.

Although construction inspection records indicate the presence of some deleterious particles in excess of the 3-percent maximum permitted by the standard specifications at all stockpile sites along this portion of I 94, at four of these sites (involving 5 of the 18 projects) these particles were present in what may be considered significant quantities. In all four cases, the aggregate came from Source No. 7. At three of these stockpile sites, heavier, better-quality aggregate was shipped in to improve or "sweeten" the stockpiles, as indicated in Table 3. In spite of this attempt at improving coarse aggregate quality, the five projects containing the sweetened mix ranked 8th, 10th, 12th, 13th, and 15th of the 18 projects in popout frequency (Table 1). Although sweetening succeeded in bringing these stockpiles up to specification standards, the resulting pavement clearly reflects the influence of the deleterious material.

TABLE 3
PROJECTS WITH DELETERIOUS AGGREGATE AND "SWEETENING"
(Ranked best to poorest by popout frequency)

Project*	Year Completed	Aggregate from Primary Source				"Sweetening" Aggregate (Source 12)		Total Aggregate, Tons	Remarks
		Acceptable Aggregate		Deleterious Aggregate **					
		Tons	Percent of Total Aggregate	Tons	Percent of Total Aggregate	Tons	Percent of Total Aggregate		
G	1960	18,086	93.8	669	3.5	537	2.7	19,292	Highest deleterious content in a single test: 3.7 percent
I	1960	14,472	75.6	1135	5.9	3531	18.5	19,138	Highest deleterious content in a single test: 4.3 percent
J	1959	16,538	80.4	4040	19.6	unsweetened	----	20,578	Highest deleterious content in a single test: 6.3 percent
L & M	1959	unknown	----	3636	13.6	unknown	----	26,809	Inspection reports noted sweetening aggregates brought in, without stating quantities

* Same project code as Table 1.

** Quantity tested and used even though deleterious material exceeded the maximum permitted according to specifications (3 percent).