EXPERIMENTAL CONCRETE CAPPING ON GROESBECK HIGHWAY
Project F 50-7, C5
Third Progress Report

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Joint Investigation of Office of Construction
and Office of Testing and Research
With Approval of the Bureau of Public Roads

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In June and July 1952, Groesbeck Highway (M 97) between Eight Mile Road and Fourteen Mile Road was capped with reinforced portland cement concrete. This capping was divided into four test sections according to the method of cap application, each containing several thicknesses of cap. The work was done in connection with a research project undertaken by the Research Laboratory Division at the request of the Road Construction Division, with the approval of the Bureau of Public Roads. The general objective was to compare the performance of various capping procedures, with the goal of minimizing the frequency and severity of uncontrolled transverse cracks occurring in this type of construction.

The general plan of the study and the construction procedures were described in Research Laboratory Division Report 194 (Aug. 20, 1953). In that report, it was stated that the investigation had two parts:

> "1. To determine the location and number of cracks per slab of concrete capping as recorded immediately after removal of curing paper and before pavement was opened to traffic.
>
> "2. To determine the number of cracks per slab appearing after opening the pavement to traffic. This will be accomplished by periodic condition surveys over a long period of time."

The first portion of the investigation was covered in Report 194. The second aspect is dealt with in Report 206 (Apr. 16, 1954), and in the current report.

As shown in Fig. 1, the portion of M 97 involved in the investigation included 7.1 mi of pavement, northeast from the north Detroit city limit (Eight Mile Road) toward Mt. Clemens. The south 5.8 mi (F 50-7, C2) was built in 1928, the north 1.3 mi in 1930 (F 50-7, C3). In 1952, the test area carried average 24-hour traffic volumes of 14,000 vehicles near

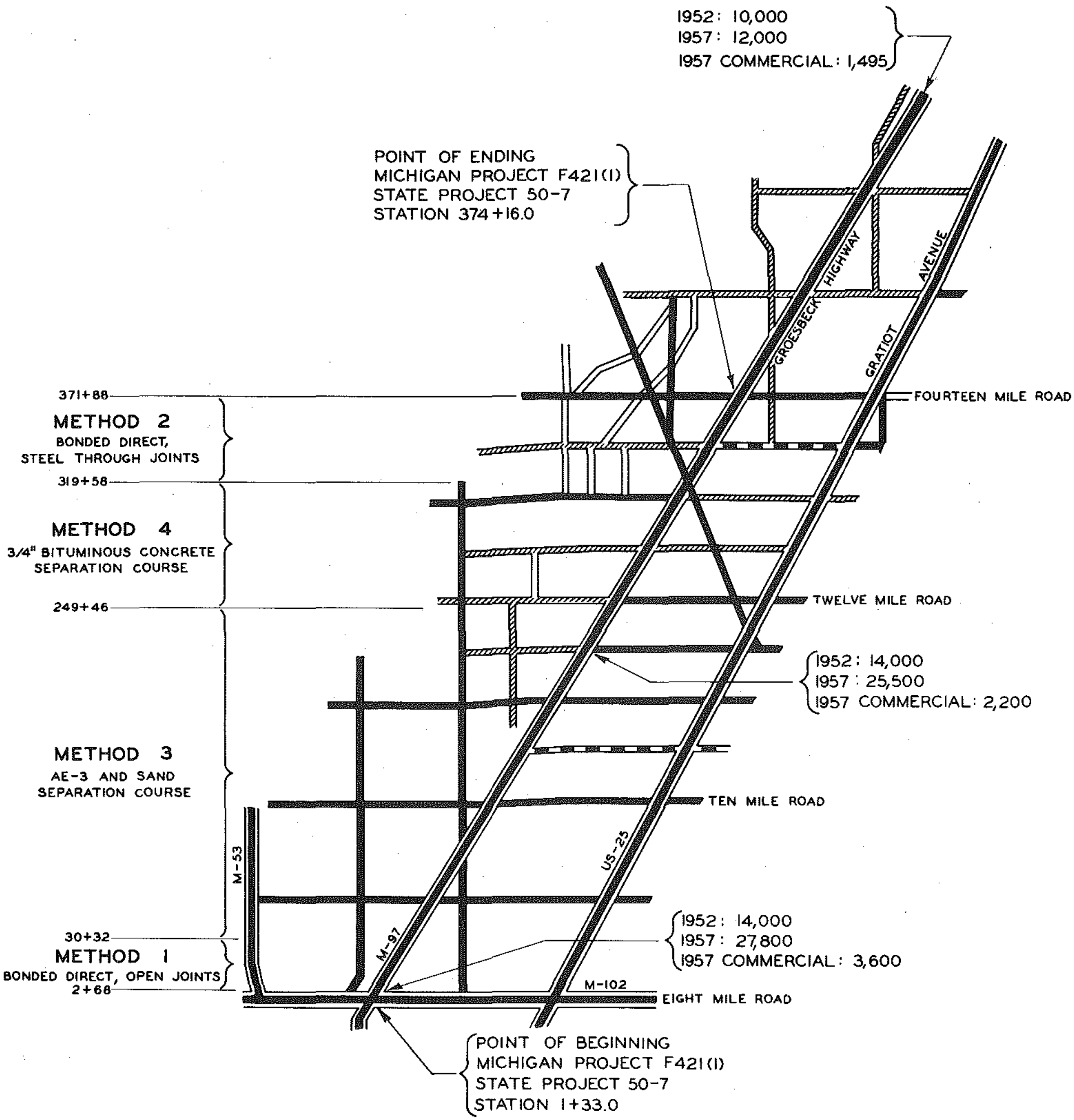
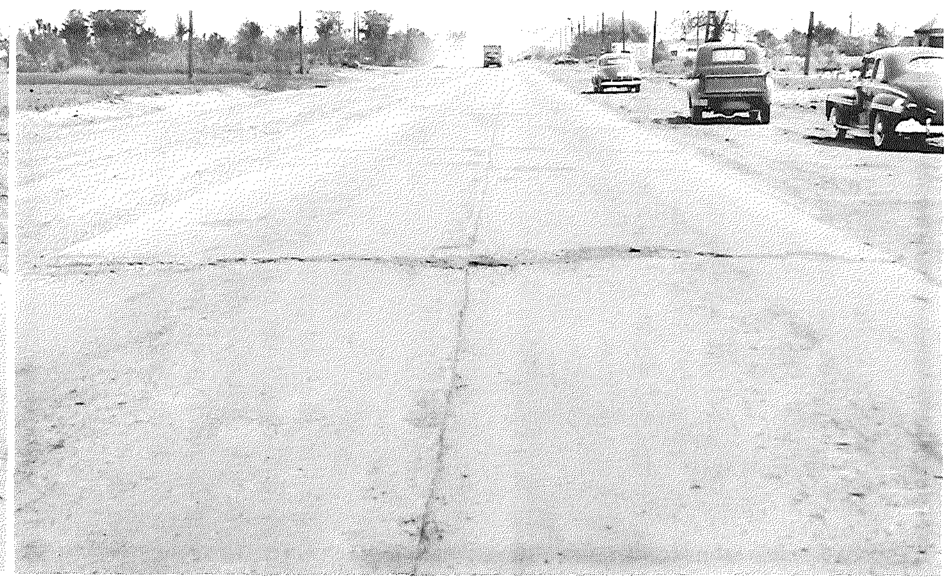


Figure 1. Plan view of capping test areas showing traffic volumes

North from 218+00

South from 218+00

North from 190+00



North from 147+00

Figure 2. Typical condition of 24-year-old concrete pavement prior to capping and widening (photos: June 1952).

Eight Mile Road, and 11,000 vehicles near Fourteen Mile Road. Approximately 13.5 percent was commercial traffic. By 1957, the traffic volume was 98 percent greater at the south end and 20 percent greater at the north.

The original pavement had deteriorated considerably in its quarter-century of service. In addition to the influences of heavy traffic and of notably poor foundation materials and drainage, the pavement surface was heavily marked with scaling and bituminous patching (Fig. 2).

The test sections may be summarized as follows:

Method 1. From Station 2+68 to 30+32: the concrete capping was bonded directly to the existing pavement.

Method 2. From 319+58 to 371+88: the capping was also bonded directly to the old pavement. In this section the steel reinforcement was carried through the cap contraction joints by error. As soon as this condition was discovered, the contractor was authorized to saw the joints to a depth sufficient to cut the welded wire mesh. However, subsequent core samples show that in some cases these attempts were unsuccessful (Fig. 3).

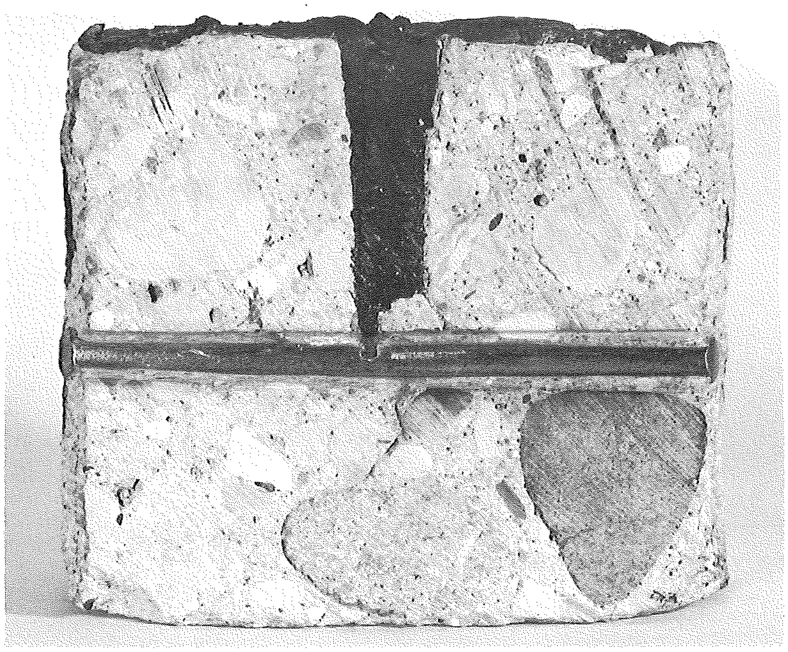


Figure 3. Concrete capping bonded direct to old pavement. An effort to saw through welded wire mesh was unsuccessful.

Method 3. From 30+32 to 249+46: a separation course was used, consisting of a single application of asphalt emulsion AE-3 and sand, composed of 0.25 gal of emulsion to 40 lb of sand per sq yd.

Method 4. From 249+46 to 319+58: a 3/4-in. bituminous concrete separation course was applied between the old pavement and the new concrete cap.

Capping thickness was intentionally varied within the section devoted to each method. The first method had thicknesses of 5, 5-1/2, and 6 in.; the second and third had thicknesses of 5, 5-1/2, 6, 6-1/2, and 7 in.; and the fourth had all these plus a stretch of 7-1/2-in. capping. In conjunction with the capping, 10-in.-uniform widening lanes were added right and left of the old pavement lanes.

The condition of this concrete pavement capping has been observed frequently since construction. In addition, a photographic log of the most prominent cracks and other physical defects was obtained during the six formal condition surveys.

Cracking

Table 1 presents the average number of cracks per slab for the various thicknesses and methods of bonding concrete to the original pavement. Although crack surveys were made each year, values shown are for the condition surveys of 1952 and 1953, 1955 and 1956, and 1958 and 1959, which represent three progressive stages in the development of cracking.

Table 2 compares the ratios of cracking for Methods 1, 2, and 4 with that of standard Method 3, for all capping thicknesses except 7-1/2 in. This table shows that Methods 3 and 4 had far fewer transverse cracks than Methods 1 and 2, and appear to have controlled cracking with approximately equal effectiveness throughout the test period for all capping thicknesses.

Figure 4 shows the relation of capping method and thickness to the number of cracks per slab. The graph shows the general tendency toward greater resistance to cracking with increasing cap thickness. Some bars diverge from this pattern; several explanations may be offered for these apparent inconsistencies:

1. There has been no attempt to measure the specific effects which standard welded wire mesh reinforcement may have had on preserving

TABLE 1
AVERAGE CRACKS PER SLAB FOR FOUR CAPPING METHODS

	Capping Method	Section Length, ft	Capping Thickness, In. 5 '52	5 '53	5 '55	5 '56	5 '58	5 '59	5-1/2 '52	5-1/2 '53	5-1/2 '55	5-1/2 '56	5-1/2 '58	5-1/2 '59	6 '52	6 '53	6 '55	6 '56	6 '58	6 '59
1*	Bonded direct to old pavement; reinforcement not carried through joints	1300 1200 300	4.5	7.5	7.5	8.4	8.8	8.9	3.3	5.2	5.3	5.5	6.9	7.0	5.3	7.5	7.7	7.8	8.7	8.7
2*	Bonded direct to old pavement; reinforcement carried through joints	500 2000 1300 900 600	8.7	10.8	12.2	12.4	12.4	12.4	7.0	9.0	9.2	9.5	9.5	9.5	6.5	7.7	8.6	8.6	8.7	8.7
3	AE-3 and sand separation course (Standard Method)	1500 8000 4700 2400 5400	1.3	2.5	2.5	2.8	3.8	3.8	2.5	3.8	4.0	4.3	5.1	5.1	2.0	2.7	2.9	3.2	4.3	4.3
4	3/4-in. bituminous concrete separation course	400 1100 3100 300 900 1200	2.3	3.4	3.4	3.4	4.9	4.9	3.1	3.9	4.2	4.3	4.5	4.5	1.1	1.8	2.1	2.1	3.4	3.4

	Capping Method	Capping Thickness, In. 6-1/2 '52	6-1/2 '53	6-1/2 '55	6-1/2 '56	6-1/2 '58	6-1/2 '59	7 '52	7 '53	7 '55	7 '56	7 '58	7 '59	7-1/2 '52	7-1/2 '53	7-1/2 '55	7-1/2 '56	7-1/2 '58	7-1/2 '59
1*	Bonded direct to old pavement; reinforcement not carried through joints																		
2*	Bonded direct to old pavement; reinforcement carried through joints	6.3	7.5	8.3	9.1	9.1	9.1	6.4	7.5	8.2	8.2	8.2	8.2						
3	AE-3 and sand separation course (Standard Method)	0.7	1.1	1.2	1.3	3.1	3.1	0.5	1.0	1.2	1.4	2.2	2.2						
4	3/4-in. bituminous concrete separation course	0.7	1.2	1.3	1.5	2.3	2.3	0.0	0.4	0.6	0.8	1.6	1.6	2.1	2.6	2.7	2.8	4.1	4.1

* Planned as one method; through construction error, reinforcement was continued through capping contraction joints in 5300 ft which are designated "Method 2."

TABLE 2
CRACKING RATIOS FOR FOUR CAPPING METHODS
Ratios Based on Standard Method: AE-3 and Sand as Breaker

	Capping Method	1952 5	1952 5-1/2	1952 6	1952 6-1/2	1952 7	1953 5	1953 5-1/2	1953 6	1953 6-1/2	1953 7	1955 5	1955 5-1/2	1955 6	1955 6-1/2	1955 7
1*	Bonded direct to old pavement; reinforcement not carried through joints	3.5	1.3	2.7	---	---	3.0	1.4	2.8	---	---	3.0	1.3	2.7	---	---
2*	Bonded direct to old pavement; reinforcement carried through joints	6.7	2.8	3.3	9.0	12.8	4.3	2.4	2.9	6.8	7.5	4.9	2.3	3.0	6.9	6.8
3	AE-3 and sand separation course (Standard Method)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	3/4-in. bituminous concrete separation course	1.8	1.2	0.6	1.0	0.0	1.4	1.0	0.7	1.1	0.4	1.4	1.1	0.7	1.1	0.5

	Capping Method	1956 5	1956 5-1/2	1956 6	1956 6-1/2	1956 7	1958 5	1958 5-1/2	1958 6	1958 6-1/2	1958 7	1959 5	1959 5-1/2	1959 6	1959 6-1/2	1959 7
1*	Bonded direct to old pavement; reinforcement not carried through joints	3.0	1.3	2.4	---	---	2.3	1.4	2.0	---	---	2.3	1.4	2.0	---	---
2*	Bonded direct to old pavement; reinforcement carried through joints	4.4	2.2	2.7	7.0	5.9	3.3	1.9	2.0	2.9	3.7	3.3	1.9	2.0	2.9	3.7
3	AE-3 and sand separation course (Standard Method)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
4	3/4-in. bituminous concrete separation course	1.2	1.0	0.7	1.2	0.6	1.3	0.9	0.8	0.7	0.7	1.3	0.9	0.8	0.7	0.7

* Planned as one method; through construction error, reinforcement was continued through capping contraction joints in 5300 ft which are designated "Method 2."

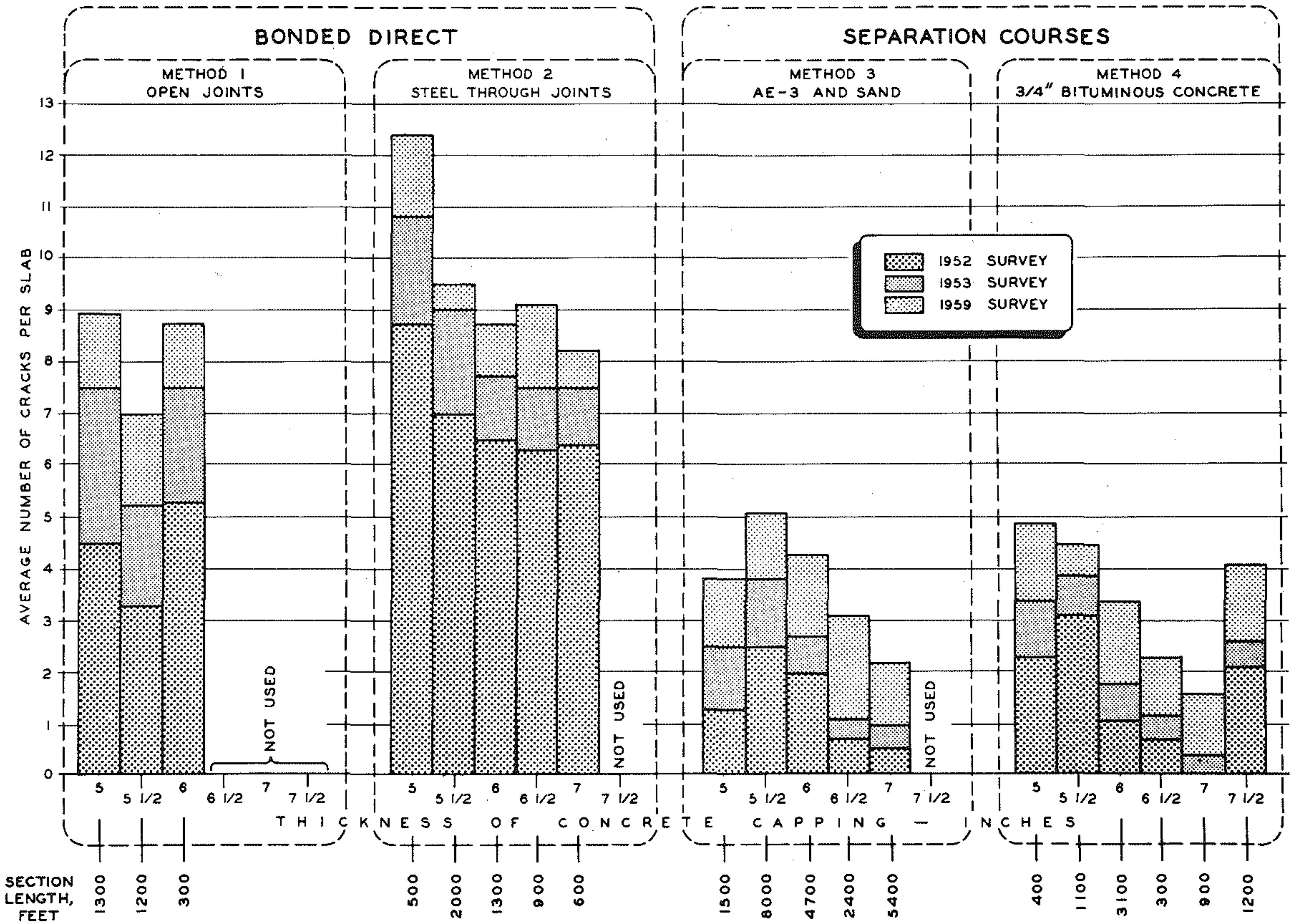


Figure 4. Relation of capping methods and thicknesses to number of cracks per slab prior to opening (1952), after one year (1953) and after seven years (1959).

the continuity of capping installations using six different concrete thicknesses. Further, the varying foundation soils and the wide range of structural conditions encountered in the 7.1 mi of the original pavement have not been included as variables in the research project. The primary parameter under consideration has always been the relative sufficiency of the various bonding methods.

2. The 19 different test-section lengths involved complicate the computation of comparative performance data. For example, the Method 1 bars include three thicknesses of cap; but, bars for 5-in. and 5-1/2-in. caps were averaged from slabs in sections 1300 and 1200 ft long, while the 6-in. bar derived from performance of only 300 ft of resurfacing, only a fourth the linear distance involved in the other two Method 1 sections.

However, the greatest portion of the evidence in Table 1 and Figure 4 indicates that Methods 3 and 4, involving introduction of separation courses before application of concrete caps, are for all practical purposes comparable and similar in performance and are both superior from the standpoint of crack experience to methods in which capping was bonded directly to the old pavement.

Patching

Further comparison of the capping applied with and without separation courses between the old pavement and the cap course, shows a curious contradiction in two performance characteristics. The separation-course capping underwent less transverse cracking (Tables 1 and 2), but more joint repair (Table 3) during the seven years. This joint repair was made under heavy maintenance contracts in 1957, 1958, and 1959. This might

TABLE 3
CONCRETE PATCHING REPAIR FOR FOUR CAPPING METHODS
1959 Condition Survey

Type	Capping Method	Percent Repaired		
		Joints	Cracks	Area
Without Separation Course	1	3.4	0.00	0.22
	2	7.6	0.24	1.37
		average 5.5	average 0.12	average 0.80
With Separation Course	3	5.8	0.04	0.74
	4	12.2	0.00	1.29
		average 9.0	average 0.02	average 1.02

be expected, for a separation course would reduce tensile forces in the capping due to temperature variation, because of a lower coefficient of friction between the two surfaces.

Also, the greater amount of joint repair required in areas with separation courses might be attributed to differential curling of the cap and old pavement, as opposed to the more monolithic curling of old pavement with a directly bonded cap. If differential curling is greater when separation courses are used, then the concrete cap would be subjected to impact forces; in the curled condition, the cap would be deflected downward by a wheel load at a joint, suddenly striking the firm and rigid mass of the old pavement, and eventually incurring physical damage (Figs. 17, 19, 20, 21).

Thus, at joints, the cap with a separation course is somewhat similar to the joint-sill construction sometimes used in Europe, where a rigid sill is placed beneath the transverse joint. That type of construction has also generally required excessive joint repair. While this explanation has not been substantiated by specific curling information from the Groesbeck project, it does appear very plausible and consistent with known data.

The loss of bituminous separation course material at joints may be another contributing factor to fracturing of the concrete at certain joints.

Roughness

In 1952, shortly after the capped and widened pavement was opened to traffic, a survey indicated average roughness values of 149 in. per mi for the entire experimental project. This is "average" riding quality according to standard classifications developed by the Department for new pavement. The individual methods were not evaluated separately in 1952, but they were recorded separately in April 1960 in order to compare the present differences in roughness.

Table 4 gives 1960 average roughness values, ranging from 168 to 186 in. per mi. This represents "average" to "poor" riding quality, again in terms of the standard classifications for new pavements.

Regarding relative performance of the individual methods, the 1960 figures conform to the general crack performance pattern, but also show the capping to have remained somewhat smoother than might have been anticipated. The four methods are fairly equal in quality. The average driver would notice no significant variation in riding comfort for the four sections. Within this close roughness range, Method 4 is best and Method

TABLE 4
SECTIONAL ROUGHNESS FOR FOUR CAPPING METHODS

Capping Method	Roughness, in. /mi		
	Northbound	Southbound	Average
1	172	201	186
2	175	172	174
3	170	187	178
4	169	166	168

1 poorest, although it should be noted that Method 4 contains the largest percentage and Method 1 the smallest percentage of pavement patch repair.

A comprehensive photographic survey has been appended to this report (Figs. 5-23). By comparing this visual evidence with the performance data in Tables 1 through 4, one may observe the progressive development of cracking and joint deterioration through the seven-year history of the study.

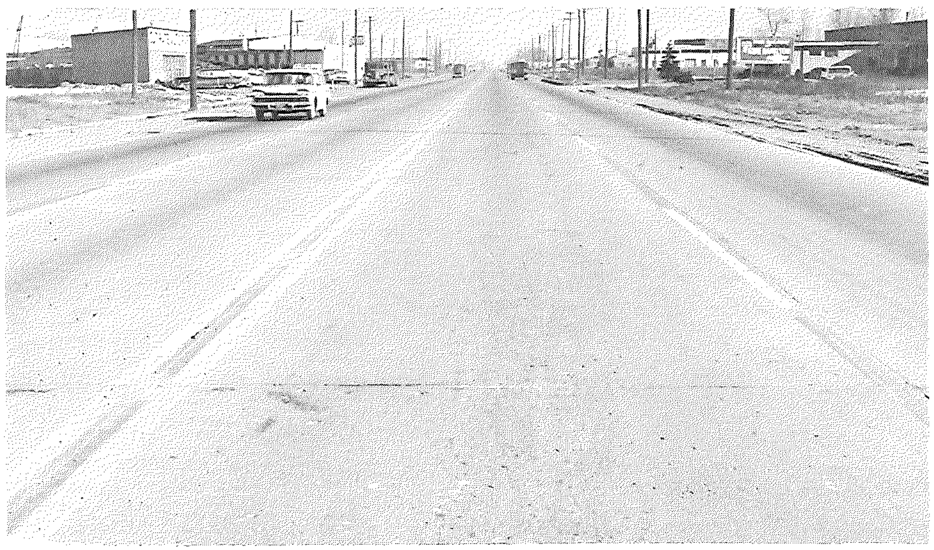
This construction project has now reached an age where certain statements may be made concerning its performance to date:

1. The application of a separation course between the original pavement and the concrete cap (Methods 3 and 4) produces less cracking than when the cap is bonded directly to the old pavement (Method 1).

2. In general, the increased thickness of concrete capping is beneficial in reducing cracking of the cap.

Method 1: Direct bonding, open contraction joints. North from 23+00.

Method 2: Direct bonding, reinforcement through contraction joints. North from 346+00



Method 3: AE-3 and sand separation course. North from 128+00

Method 4: 3/4-in. bituminous concrete separation course. North from 261+00

Figure 5. General views of surface condition of 7-year-old concrete capping (Feb. 1960)

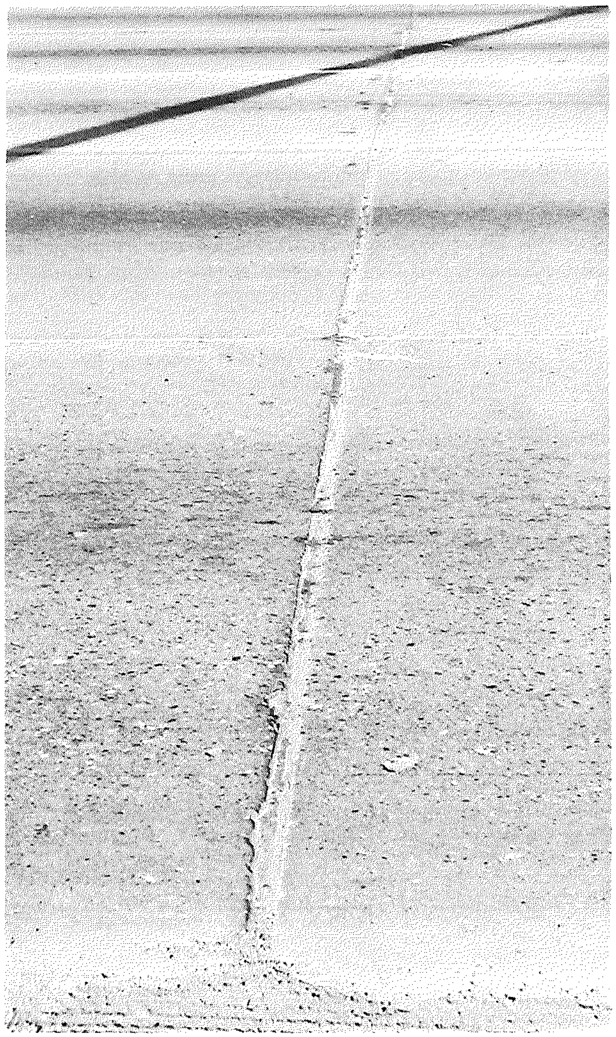
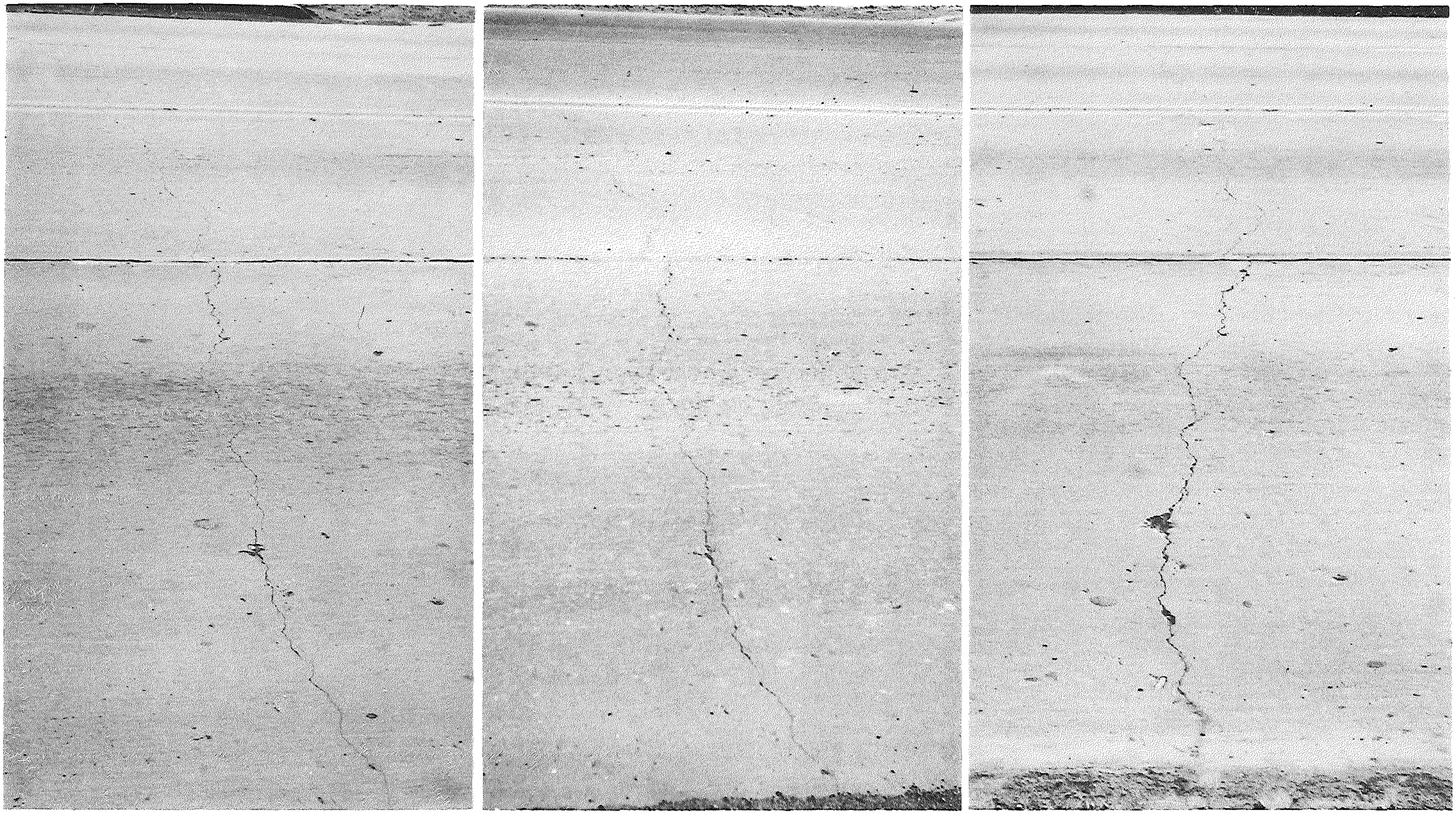


Figure 6. Typical sound contraction joint in 5-in. capping and adjacent widening (foreground), after 7 years. (Feb. 1960). 4+41 - Method 1.

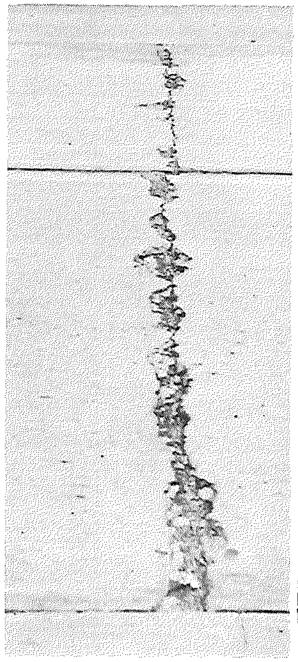
Figure 7. Joint failure in 5-1/2-in. capping, resulting in patching of center lanes (Feb. 1960). 7+35 - Method 1.

Figure 8. Minor joint deterioration in 5-1/2-in. capping and adjacent widening (Feb. 1960). 28+33 - Method 1.



May 1955 | April 1956 | December 1959

Figure 9. Progressive transverse cracking in 5-1/2-in. capping (center lanes) continuing into foreground widening lanes, at 3, 4, and 7 years. 27+77 - Method 1.

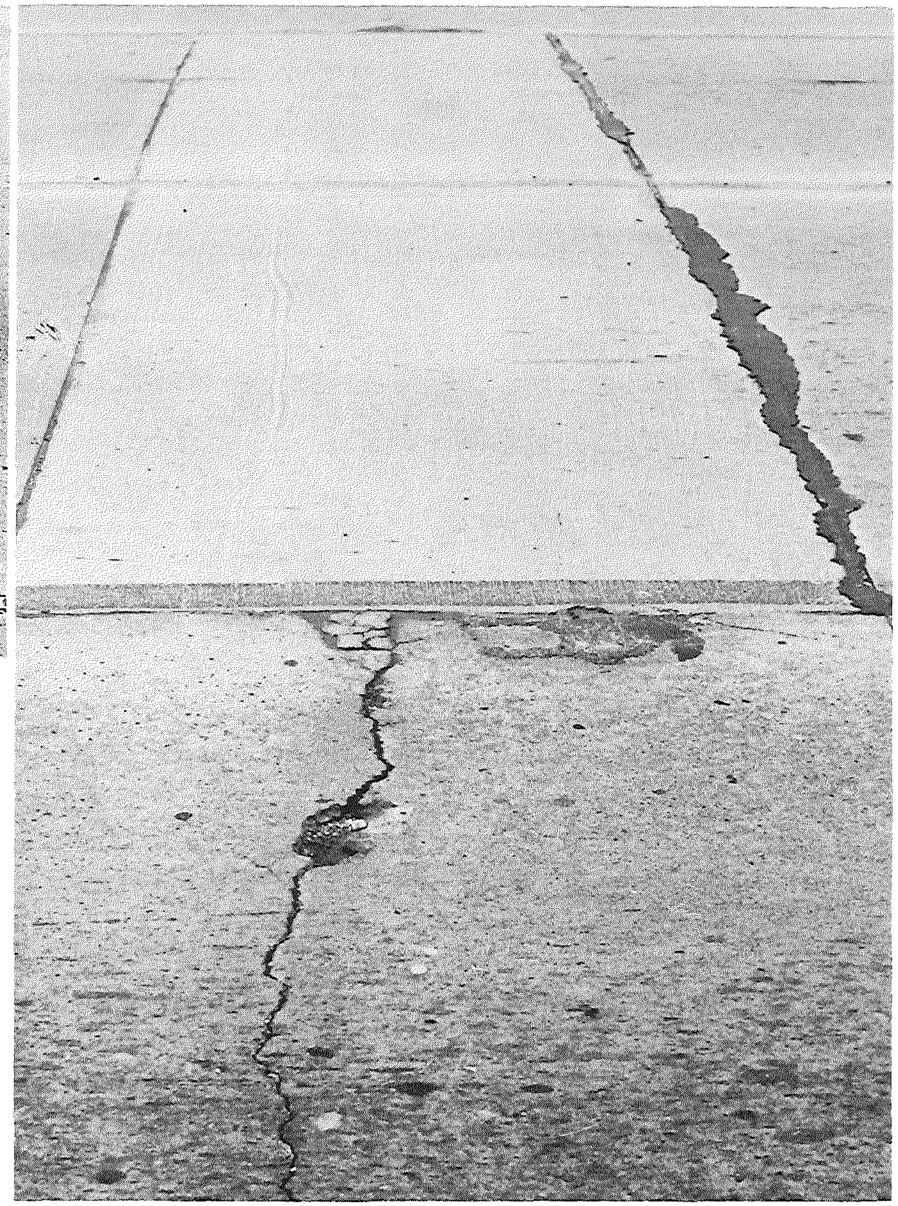


November 1952

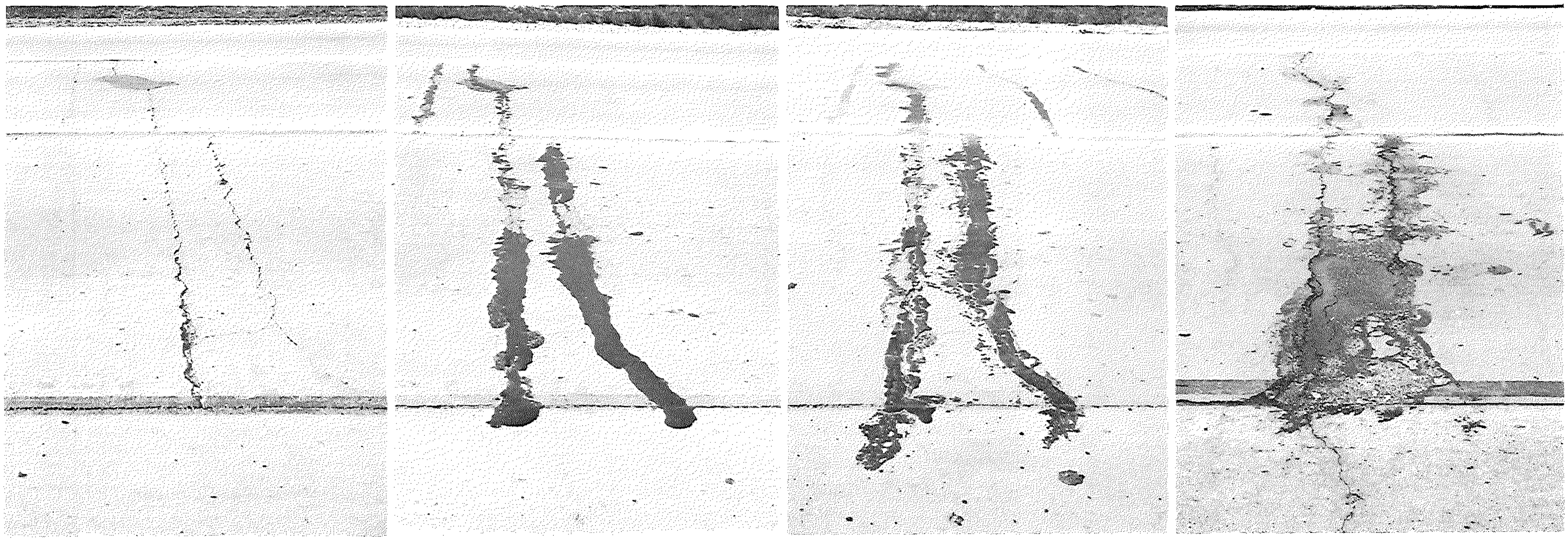
November 1953

February 1958

Figure 10. Crack deterioration resulting in patching of 5-in. capping (center lanes); note transverse crack at same point in foreground widening lane. 367+21 - Method 2.



December 1959

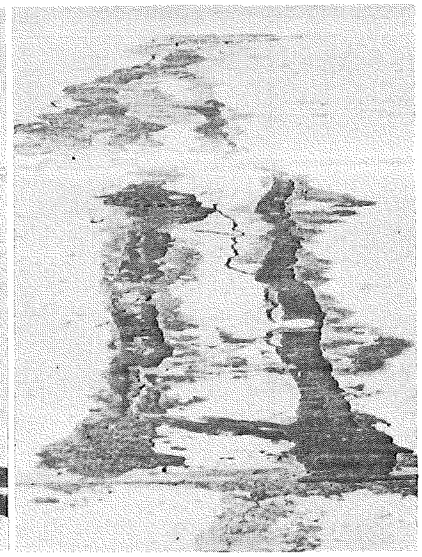


November 1953 May 1955 April 1956 December 1959

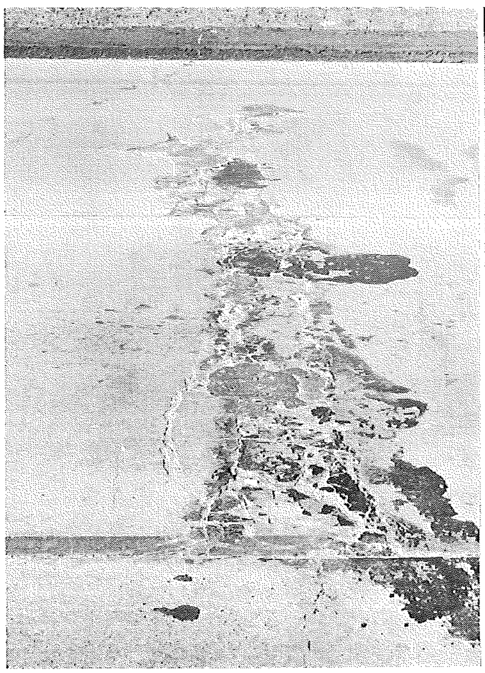
Figure 11. Adjacent cracks in 5-1/2-in. capping received sealer and local bituminous patching.
359+50 - Method 2.

November 1953

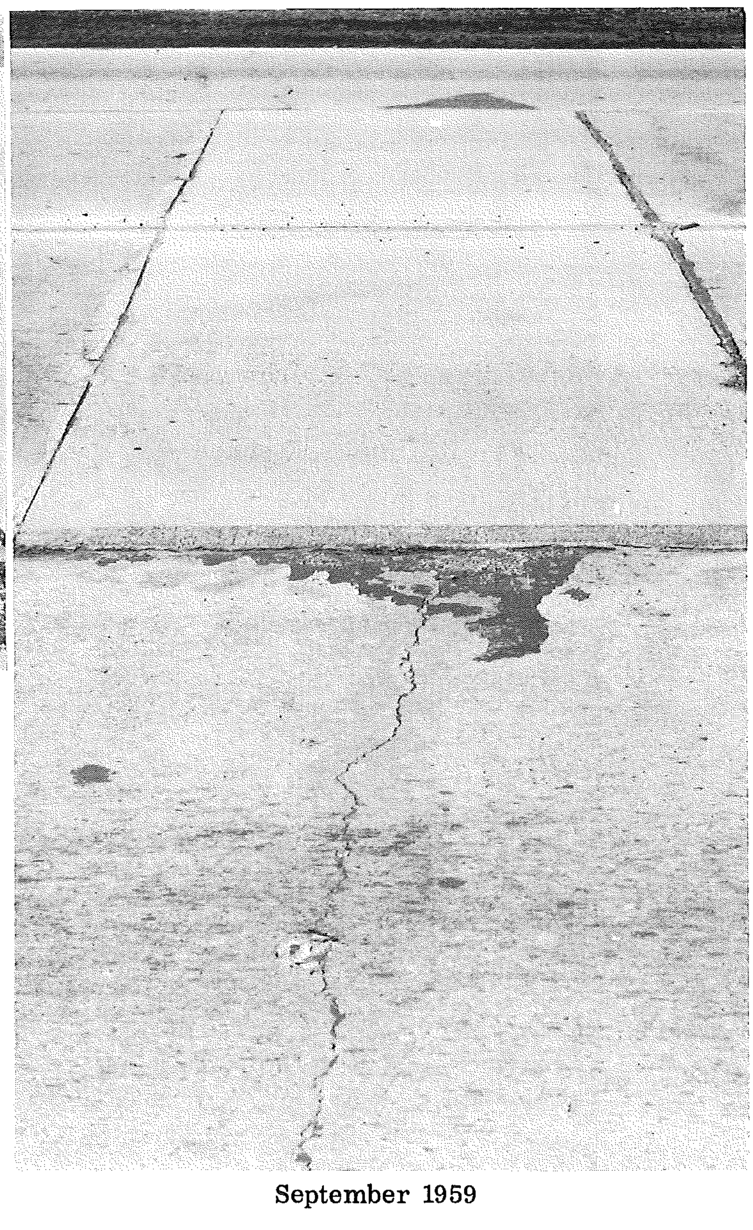
May 1955



April 1956

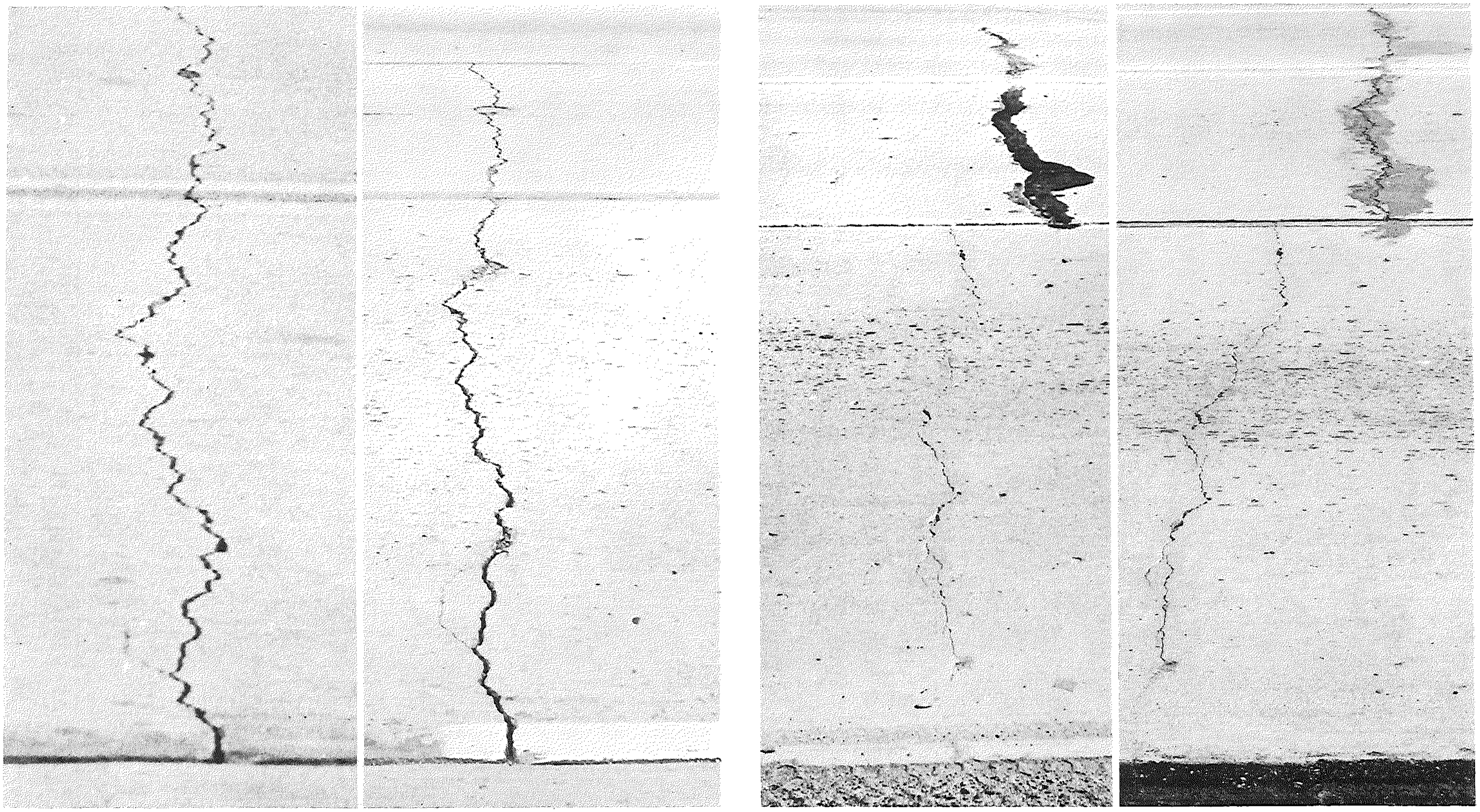


February 1958



September 1959

Figure 12. Adjacent cracks eventually required patch in 6-in. capping; note transverse crack at same point in foreground widening lane. 368+20 - Method 2.



November 1952 | November 1953 | April 1956 | December 1959

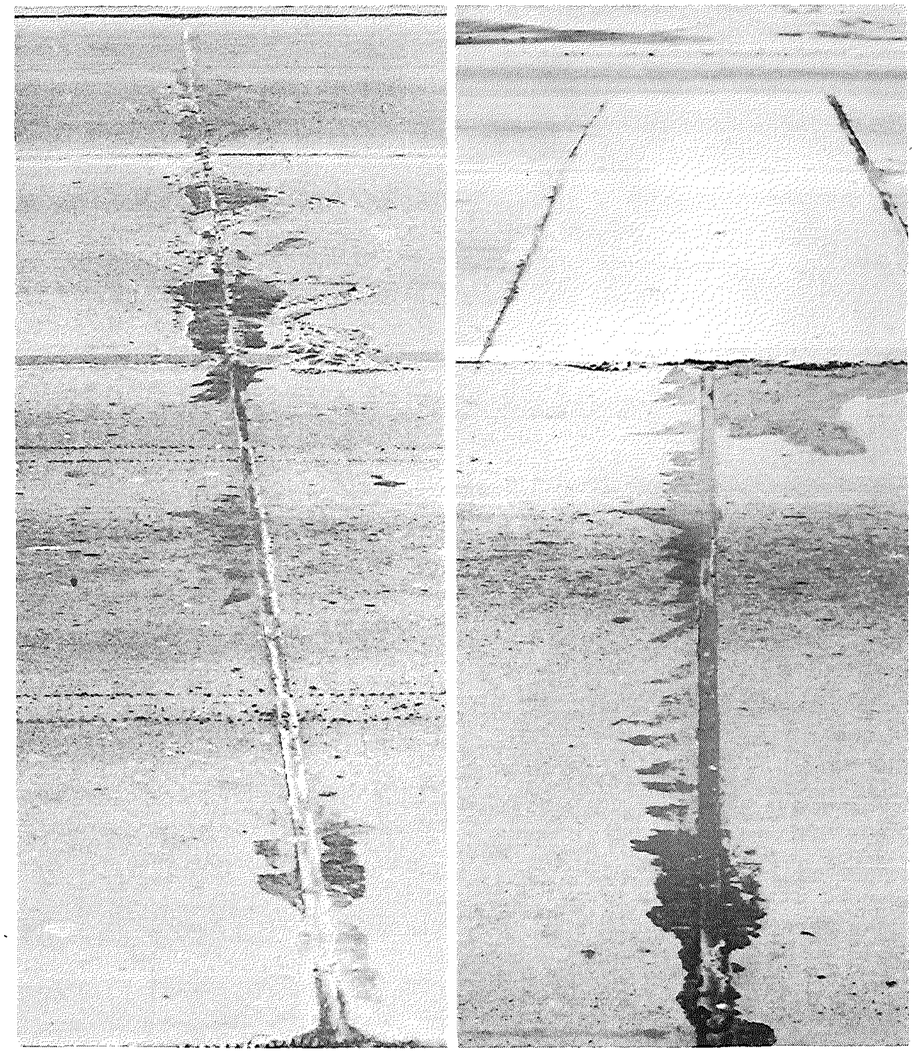
Figure 13. Progressive widening of crack in 6-1/2-in. capping. The 1952-53 views are from the west pavement edge; the 1956-59 views from the east. In 1956-59 views, note crack development in right widening lane. 348+49 - Method 2.

Figure 14. Contraction joint deterioration in 6-1/2-in. capping (center lanes) after 7 years (Dec. 1959). 353+67 - Method 2.

Figure 15. Crack in 6-1/2-in. capping continued in foreground widening lane, after 7 years (Feb. 1960). 350+48 - Method 2.

May 1955 December 1959

Figure 16. Transverse crack in 6-in. capping at 3 and 7 years. 154+09 - Method 3.



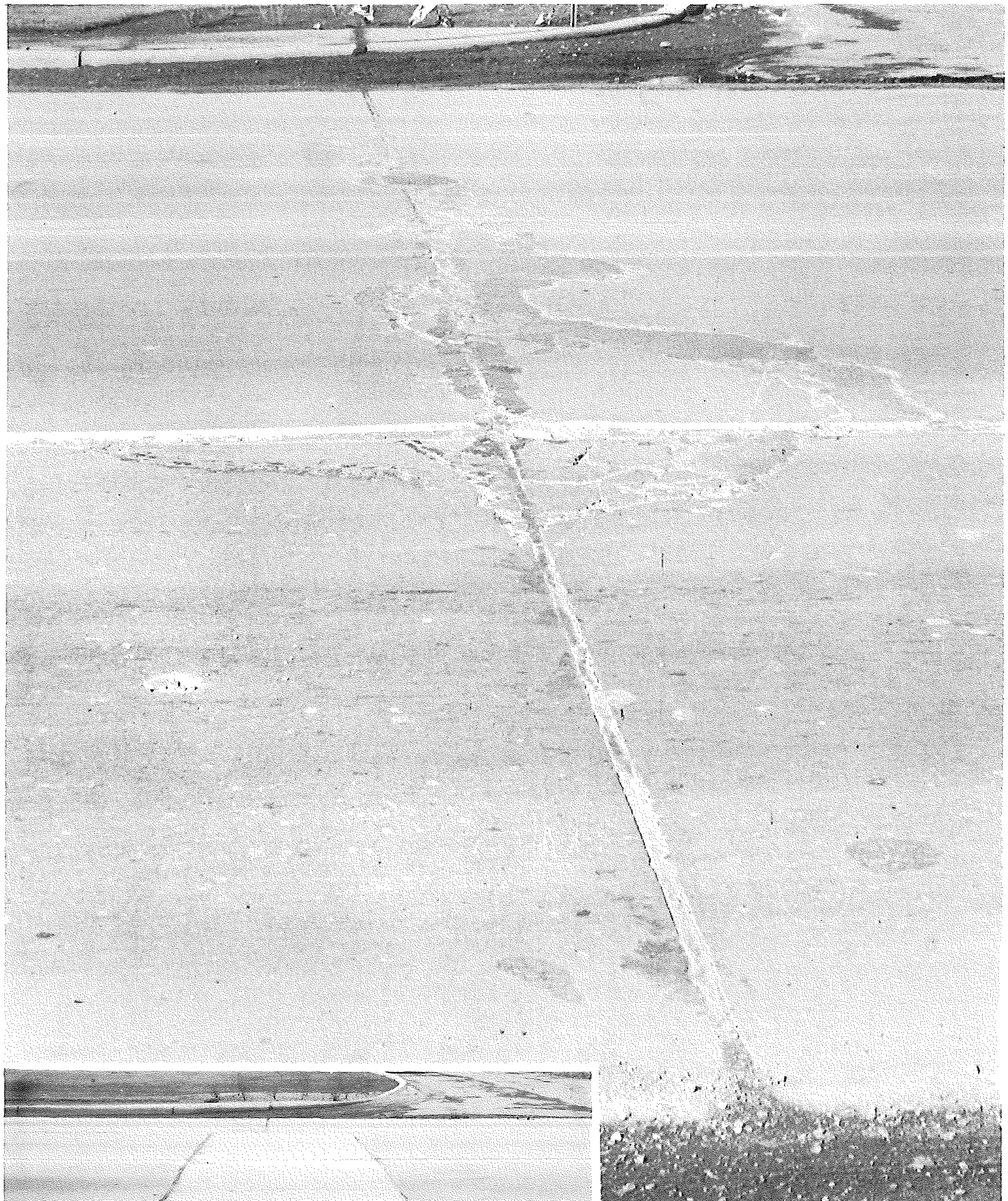
February 1958 December 1959

Figure 17. Severe deterioration in 6-in. capping at construction joint required patch (center lanes). 172+65 - Method 3.

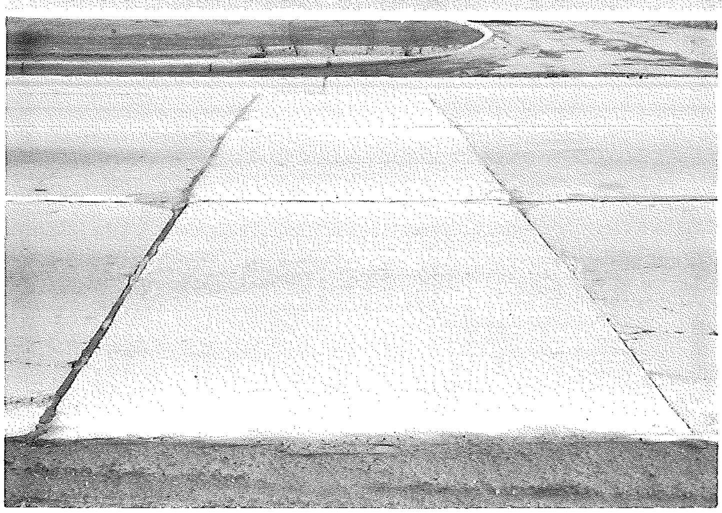
May 1955

December 1959

Figure 18. Widening of transverse crack in 7-in. capping in center lanes, continued in foreground widening lanes. 159+09 - Method 3.



February 1958

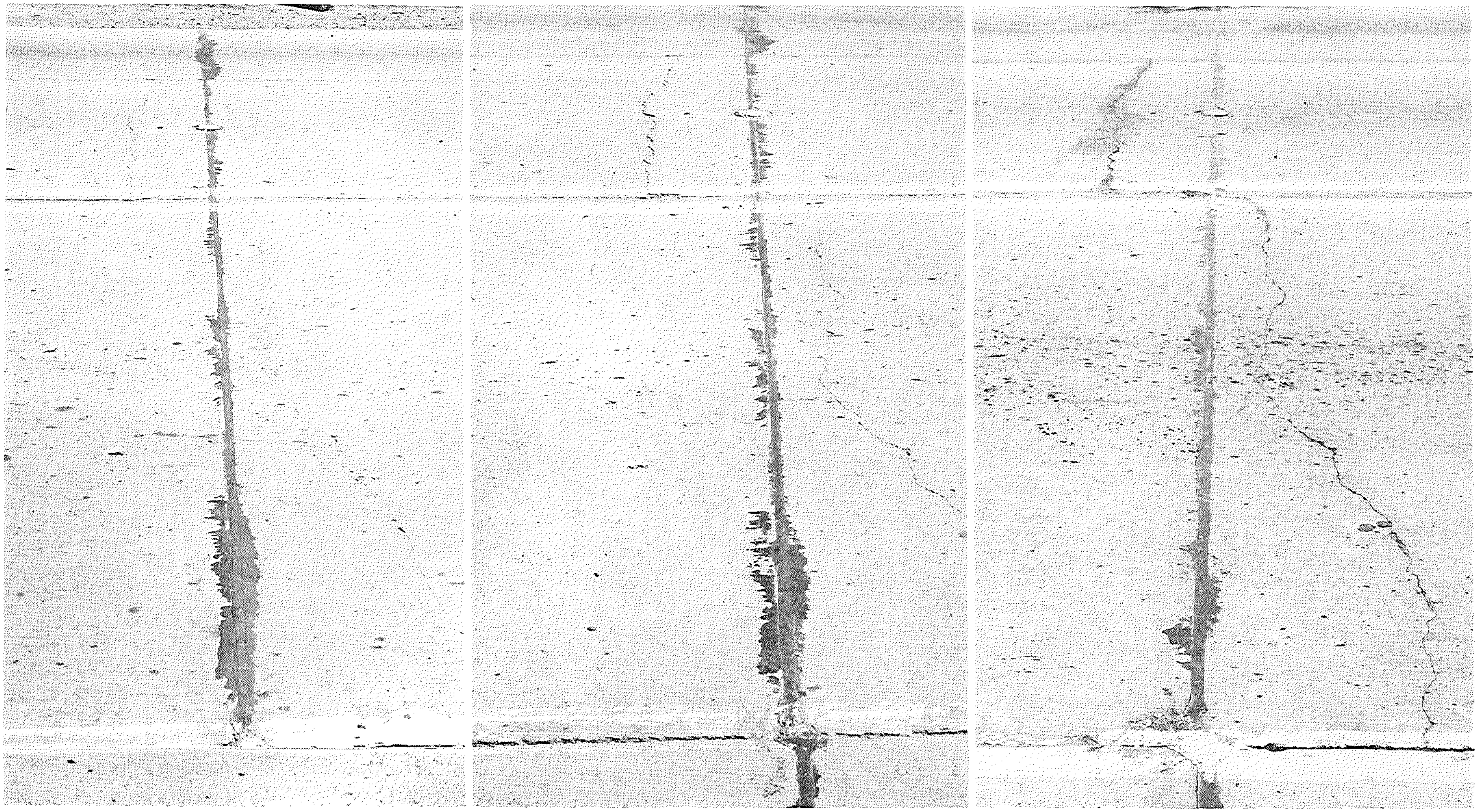


December 1959

Figure 19. Severe deterioration at contraction joint in 7-in. capping required complete replacement of cap in center lanes and of right widening lane. 192+92 - Method 3.

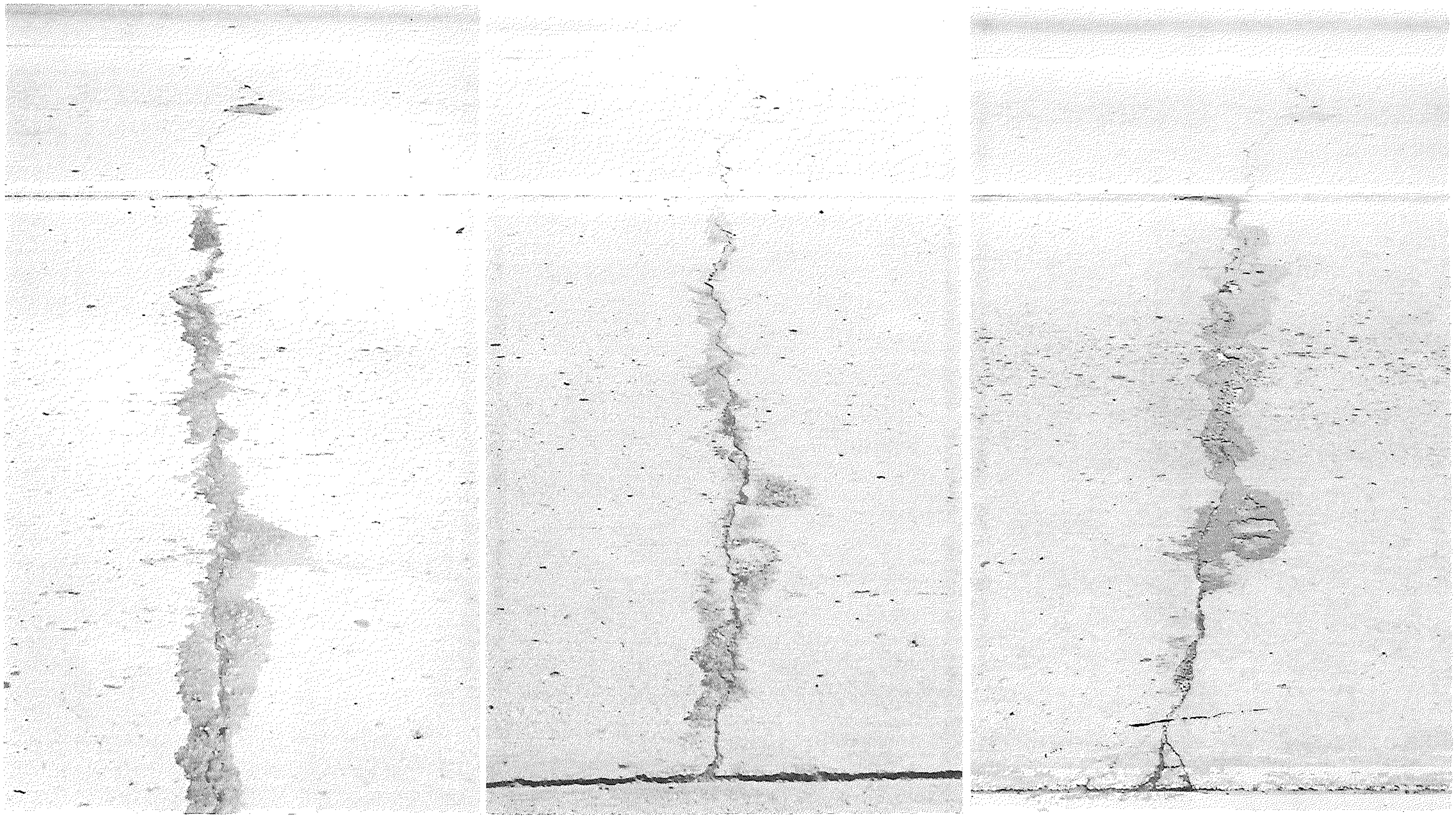
Figure 20. Repaired area at contraction joint in 6-in. capping (center lanes), with similar repair in foreground widening lanes; note concrete deterioration in widening patch (Dec. 1959). 301+97 - Method 4.

Figure 21. Repair at contraction joint in 7-1/2-in. capping with similar repair of foreground widening lane (Dec. 1959). 281+33 - Method 4.



May 1955 April 1956 December 1956

Figure 22. Contraction joint in 7-1/2-in. capping in good condition
even with adjacent transverse cracks. 271+49 - Method 4.



May 1955 | April 1956 | December 1959

Figure 23. Crack in 7-1/2-in. capping remained tight and showed minimal deterioration even after 7 years. 271+34 - Method 4.