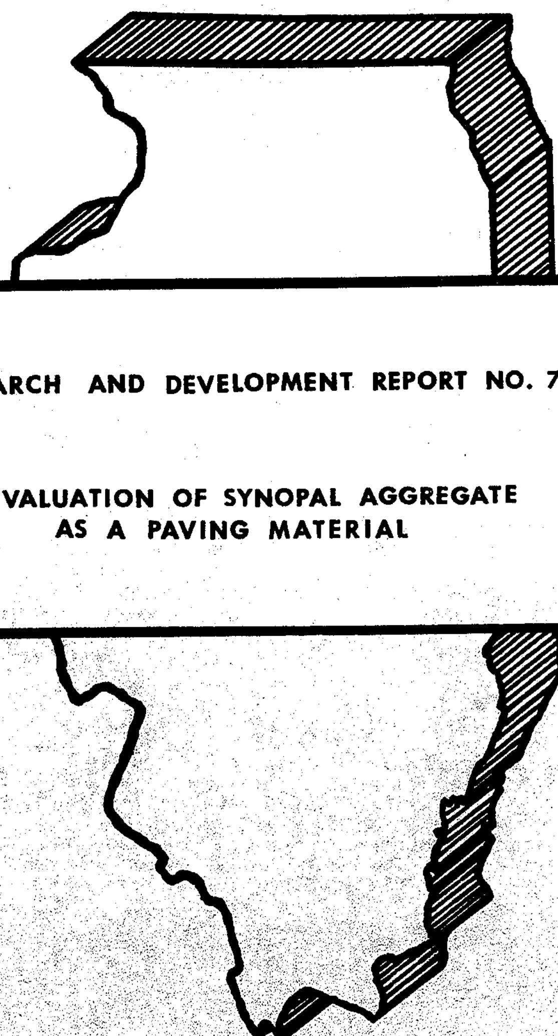
STATE OF ILLINOIS

DEPARTMENT OF PUBLIC WORKS AND BUILDINGS

DIVISION OF HIGHWAYS



RESEARCH AND DEVELOPMENT REPORT NO. 7A

EVALUATION OF SYNOPAL AGGREGATE AS A PAVING MATERIAL

RESEARCH AND DEVELOPMENT

ADMINISTRATIVE REPORT

State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

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January 1968

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SUMMARY

The study reported herein was undertaken to evaluate the properties of a synthetic aggregate, Synopal, as a paving material for use in bituminous concrete surface courses and as a bituminous surface-treatment aggregate.

Synopal is a white mineral aggregate produced by melting sand, chalk or limestone, and dolomite, cooling the molten mass to a granular state, and reheating to a temperature close to the melting point. Individual particles are hard and irregularly cubic in shape. Currently it is not manufactured in this country and apparently is available only from Europe. The material used in this study was imported from Denmark at a cost of $45 per ton delivered at the jobsite. It is reported that if sufficient demand exists, the material could be manufactured in this country to sell at $15 to $20 per ton at the plantsite. Natural aggregates available for the same usage in Illinois typically cost $1 to $2 per ton at the plantsite and another $1 to $2 per ton for delivery to the jobsite.

Synopal was developed by the engineering firm of Karl Kroyer, Viby-Aarhus, Denmark, which holds all patent rights.

In the present study, two sizes of Synopal (5-8 mm and 8-12 mm) were subjected to routine laboratory tests and to performance studies in a series of field trial installations. Of major interest in the field were the light-reflectance and skid-resistance properties imparted to bituminous concrete surfaces and to bituminous surface treatments by the Synopal aggregates. A Hunter Night-Visibility Meter was used to measure light reflectance; a Keystone Mark IV Portable Skid Resistance

Tester and a Skid Trailer owned by the Portland Cement Association were used to measure skid resistance.

Routine laboratory tests, including soundness and abrasion tests, showed Synopal to be well within Illinois Division of Highways specification limits governing aggregates for bituminous concrete and bituminous surface treatment construction.

When Synopal was substituted for a natural limestone aggregate in amounts of 25 percent and 50 percent by volume in a bituminous concrete surface course mixture, somewhat better night visibilities as measured by the Hunter Night-Visibility Meter resulted through 24 months of service under traffic. The improvement was in relation to the amount of Synopal used.

Night-visibility recordings for bituminous surface treatments having Synopal showed a slight advantage for the Synopal aggregate over a representative natural limestone aggregate available in Illinois.

Skid-test measurements showed Synopal aggregate to impart good skid-resistance characteristics to both bituminous concrete surfaces and bituminous surface treatments. Skid-resistance values for the Synopal aggregate were usually slightly better than, but of the same order as, those shown by limestone aggregates with which it was compared. In the bituminous concrete, the improvement was in relation to the amount of Synopal used.

Considerable difficulty was experienced with the adherence of the Synopal aggregate to the bituminous binder material in the surface treatment construction, even though an antistripping agent was used. Of trials made at four different locations, only one could be considered to be reasonably successful. The cause of the lack of adherence was not apparent.

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INTRODUCTION

The light reflectance, skid resistance, and color of bituminous concrete surfaces and of bituminous surface treatments are influenced in major degree by the aggregates used in their construction. Aggregates that afford a high degree of light reflectance, particularly in wet weather and after dark, that offer good resistance to skidding, and that are of a color contrasting with that of surrounding surfaces, contribute measurably to the safety and comfort of highway users.

Synopal, a synthetic aggregate, was introduced to the Illinois Division of Highways in laboratory-size quantities in 1965 as a material high in these attributes. When a sufficient amount for construction (about 800 tons) became available in the summer of 1965, several trial installations were established in the field. These included bituminous concrete overlays on a heavily traveled highway, a shoulder surface treatment, and pavement surface treatments on several existing light- and medium-traffic roads. The locations of the trial installations are shown in Figure 1.

Synopal is a white, mineral aggregate produced by melting sand, chalk or limestone, and dolomite, and cooling the molten mass to a granular state, and reheating to a temperature close to the melting point. Individual particles of Synopal are of an irregularly cubic shape and, according to trade literature, have a crushing strength 40 percent higher than that of normal granite and a hardness of 7.5 Mohs' scale (quartz is 7).

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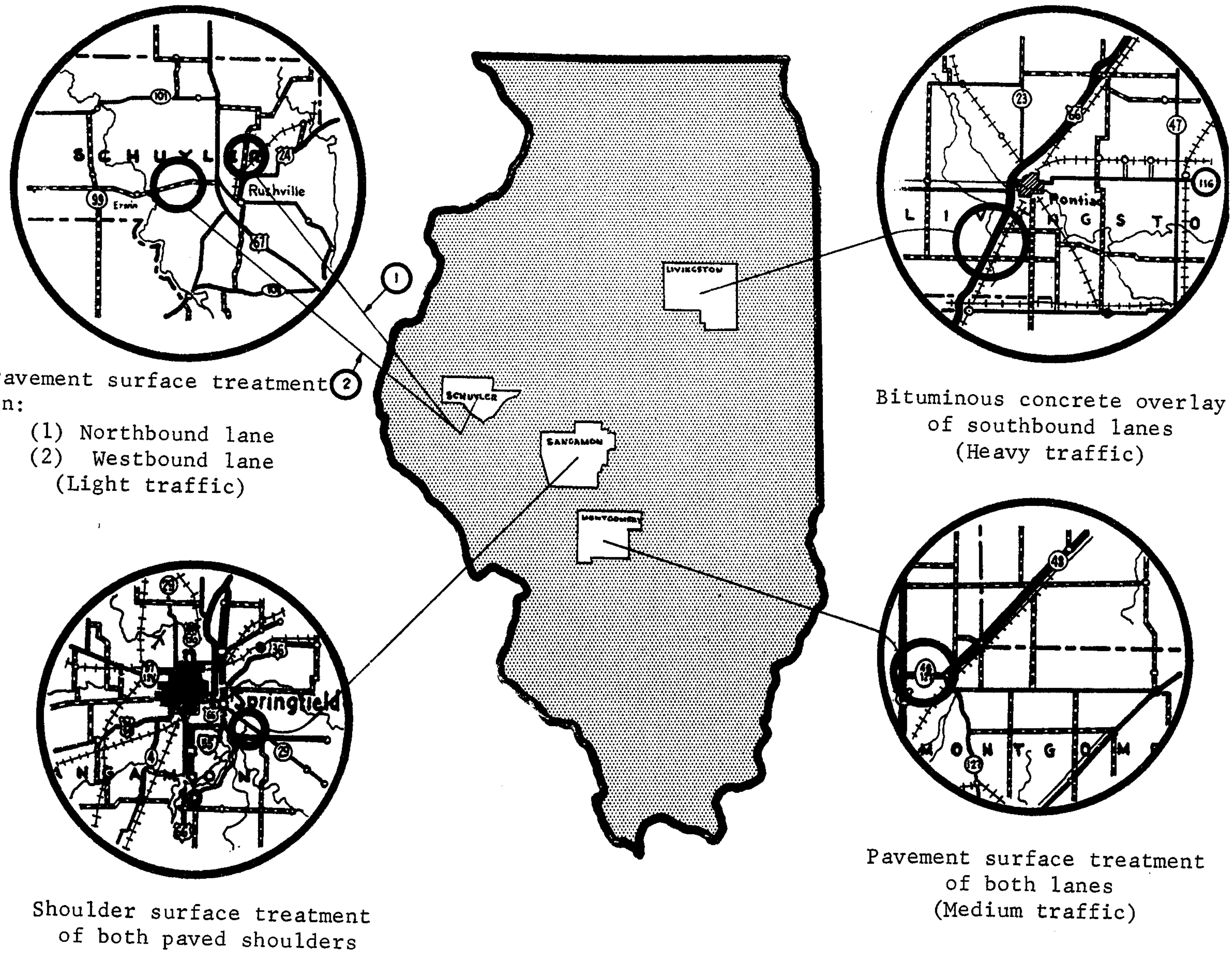

Figure 1. Locations of Synopal trial installations.

Synopal was developed by the engineering firm of Karl Kroyer, Viby-Aarhus, Denmark, which holds all patent rights. Considerable usage of the material in road construction, although primarily experimental, is reported to have taken place in several European countries and in Japan. The material used in Illinois was produced by Synopal Limited, Thisted, Denmark, and is being marketed in Illinois by the Union Contracting Company, Chicago, and was purchased at a cost of $45 per ton, delivered at the jobsite. It has been reported that the cost could be reduced to $15 or $20 per ton, f.o.b. plant, if the material were to be manufactured in this country. Natural aggregates available for for same usage in Illinois typically cost $1 to $2 per ton at the plantsite and another $1 to $2 perton for delivery to the jobsite.

The principal objective of the Synopal trial installations was to evaluate the effectiveness of Synopal aggregate with respect to

(1) the skid resistance and night visibility qualities it imparts to bituminous concrete pavements

(2) the skid resistance and night visibility qualities it imparts to bituminous surface treated pavements

(3) the color contrast between shoulders and bituminous concrete pavements it imparts when applied to the shoulder as a surface treatment.

Key items in the evaluation of the Synopal installations were a Hunter Night-Visibility Meter, a Keystone Mark IV Portable Skid Resistance Tester, and the Portland Cement Association Skid Trailer.

PHYSICAL TESTS

The Synopal aggregates used in Illinois were supplied in two sizes identified by the producer as a 5-8 mm. size and an 8-12 mm. size. Both the smaller and larger size aggregates were used in the surface treatment study. Only the smaller size aggregate was used in the bituminous concrete overlay (bituminous concrete surface course, Subclass I-11), while only the larger size aggregate was used in the shoulder treatment study.

The results of laboratory tests conducted by the Illinois Division of Highways on samples of both sizes of the material are shown in Table 1. It will be noted from the table that the test results are indicative of a satisfactory aggregate for seal-coat and bituminous-concrete construction. Although somewhat low in specific gravity as compared with natural aggregates, considerable resistance was shown in the soundness and abrasion tests, at least in comparison with natural coarse aggregates available in Illinois.

TABLE 1

RESULTS OF LABORATORY TESTS OF SYNOPAL

Test		Sample		
		5-8 mm Size		8-12 mm Size
		A	B	C
Specific Gravity, Dry		2.11	2.01	
Surface Dry		2.17	2.09	
Absorption		3.1	4.2	
Soundness (5 cycles, sodium sulphate)		0.2	0.4	
Abrasion (Los Angeles)		24.2	26.5	
Gradation Per Cent Passing Sieve	3/4 in.			100
	1/2 in.			95
	3/8 in.	100	100	35
	No. 4	24	10	0.1
	No. 10	1	2	
	No. 200		0.3	

BITUMINOUS CONCRETE OVERLAYS

The bituminous concrete overlays that include Synopal aggregate were placed as part of a 24-foot-width resurfacing of an old portland cement concrete pavement serving southbound traffic of Route US 66. The trial installations lie immediately south of Pontiac and were constructed as part of FA Route 5, Section (10, 11, 12, 13)RS, Livingston-McLean Counties, extending from Odell to Chenoa.

Average daily traffic at the location in 1965, divided about equally between the southbound and northbound pavements separated by a depressed median, totaled 9600 vehicles, inclusive of 560 single-unit and 2000 multiple-unit commercial vehicles.

Three test sections in which Synopal aggregate was substituted for part of the normal crushed stone coarse aggregate in the surface course mixture were established. Following are some details regarding them:

	Thickness		Quantity of Synopal[1/]	
Length (mi.)	Surface Course (in.)	Binder Course (in.)	By Volume of Coarse Aggregate (%)	By Weight of Total Mix (%)
1	1	2	25	13.6
1 1/2	1	2	50	26.8
1/2	1 1/2	1 1/2	50	26.8

1/ Synopal incorporated only in surface-course mixture

A control section about one mile in length consisting of 1-inch standard surface course and 2-inch binder course was constructed between the Synopal test sections to permit a direct comparison of the standard and special mixtures.

All surface courses and binder courses met the requirements of the Illinois Standard Specifications for Road and Bridge Construction, Section 46, Bituminous Concrete Binder and Surface Courses, Fine Dense Graded Aggregate, Subclass I-11.

The selection of 25 and 50 percent coarse aggregate replacement with Synopal aggregate was arbitrary. The choice of a replacement by volume rather than by weight was made because of the considerable difference between the specific gravity of the Synopal aggregate and that of the limestone coarse aggregate (apparent specific gravities of 2.25 for Synopal aggregate and 2.74 for the limestone aggregate were used in the mix-design computations).

Design of Mixtures

The bituminous concrete mixtures containing the Synopal aggregate, as well as the standard mixture used in the control section, were designed by the Marshall Method as normally applied in Illinois. The laboratory tests indicated that Marshall stability values in excess of 3000 lbs. could be expected for the Synopal aggregate mixtures as compared with somewhat less than 3000 lbs. for the standard mixture. Recommended mixture formulas for the special mixes and the control mixes, together with the results of the Marshall tests, are shown in Table 2. Typical results of tests of samples taken behind the paver are shown in Table 3. It will be noted that the gradations and asphalt contents were all within the composition limits specified for I-11 surface course mixtures. Differences in the Marshall stability values for the field samples of the three mixes are not significant.

Construction Procedure

The Synopal aggregate, the regular limestone aggregate, and the coarse and fine sands for the bituminous-concrete mixtures were blended from a four-compartment Barber-Greene cold-feed unit. Normal drying and screening processes, as well as normal procedures for adding the mineral filler and asphalt, and for weighing, batching, and mixing, were observed.

TABLE 2

RECOMMENDED MIXTURE FORMULAS

BASED ON MARSHALL METHOD OF TEST

Sieve Passing - Retained	Control Mix (percent)		25 Percent Synopal (percent)		50 Percent Synopal (percent)	
1/2 in. - No. 4	41.9)	60.0	44.6)	60.0	47.7)	60.0
No. 4 - No. 10	18.1)		15.4)		12.3)	
No. 10 - No. 40	18.6)	30.2	18.1)	29.4	17.1)	28.2
No. 40 - No. 80	6.3)		6.2)		6.0)	
No. 80 - No. 200	5.3)		5.1)		5.1)	
Passing No. 200	4.9		5.3		5.9	
PA-6 Asphalt	4.9		5.3		5.9	
Marshall Stability, lbs.	2680		3180		3450	
Marshall Flow, 1/100 in.	8.0		9.5		7.1	
Air Voids, %	2.5		2.5		2.5	

TABLE 3

TYPICAL RESULTS OF TESTS OF BITUMINOUS CONCRETE MIXTURES
(Sampled Behind Paver)

Sieve Passing - Retained	Standard I-11 Control (percent)	25% Synopal Section (percent)	50% Synopal Section (percent)	I-11 Surface Course, Composition Limits
1/2 in. - No. 4	40.2)	12.0*) 30.7) 42.7)	23.3*) 20.6) 43.9)	25-50)
	)58.1	)61.7	)58.7	)45-65
No. 4 - No. 10	17.9	1.6*) 17.4) 19.0)	3.5*) 11.3) 14.8)	10-30)
No. 10 - No. 40	19.0)	15.9)	15.6)	7-22)
No. 40 - No. 80	7.4)32.6	6.0)27.5	7.1)29.6	5-18)25-40
No. 80 - No. 200	6.2)	5.6)	6.9)	3-10)
Passing No. 200	4.7	5.6	5.8	3-7
Bitumen	4.6	5.2	5.9	4-7
Marshall Stability at 140° F., lbs.	3070	3130	3050	
Marshall Flow at 140° F., 1/100 inch	7.9	10.0	11.2	
Specific Gravity of Briquettes (d)	2.445	2.367	2.311	
Air Voids, %	2.13	1.88	1.33	
Apparent Specific Gravity (D)	2.498	2.40	2.34	

* Synopal Aggregate (5-8 mm size)

A leveling binder mixture was placed in all depressions of one inch or more in the concrete pavement and compacted before placing the regular binder course.

After the base had been prepared, RC-0 asphalt was applied at the rate of 0.036 gallon per square yard. The asphalt primer was applied to the existing pavement surface as well as to the top of each lift of binder course.

Placing of the Synopal aggregate and control surface courses was accomplished on August 17, 19, and 20, 1965. Paving advanced from north to south starting at Station 1530+25 and ending at Station 1738+70.

A single Blaw-Knox PF-180 paver with electronic leveling controls was used for paving the main line. The leveling controls were actuated by a 20-foot-long multiple-shoe ski riding over the completed binder course.

Compaction of the binder and surface courses was accomplished with two three-wheel steel rollers running in tandem, followed by a pneumatic-tired roller.

Normal paving and rolling procedures were used throughout construction, and no special problems were encountered.

Night Visibility

In an attempt to make an objective evaluation of the light reflectance of the Synopal-aggregate construction, a Hunter Night-Visibility Meter was employed in accordance with ASTM Designation D 1011-52 (1958), "Standard Method of Test for Night Visibility of Traffic Paints." The Hunter Meter is shown in Figure 2 with scotchlite and ground milk glass calibration standards.

The Hunter Meter is a comparator which measures the intensity of the reflectance of any surface and indicates the ratio of this intensity to that of an ideally diffusing white surface under identical conditions of illumination and viewing. The directions of illumination and viewing used are constant and are similar to those of night traffic. The ideally diffusing white surface (ground milk glass standard) has been assigned a luminous directional reflectance value of 1.0. A surface producing a reading of 8 would be 8 times as reflective as the standard.

It should be pointed out that the quality of diffusion is not as desirable as the quality of reflection where reflectivity is the major concern. Diffusing surfaces are relatively smooth; reflecting surfaces are relatively rough and granular.

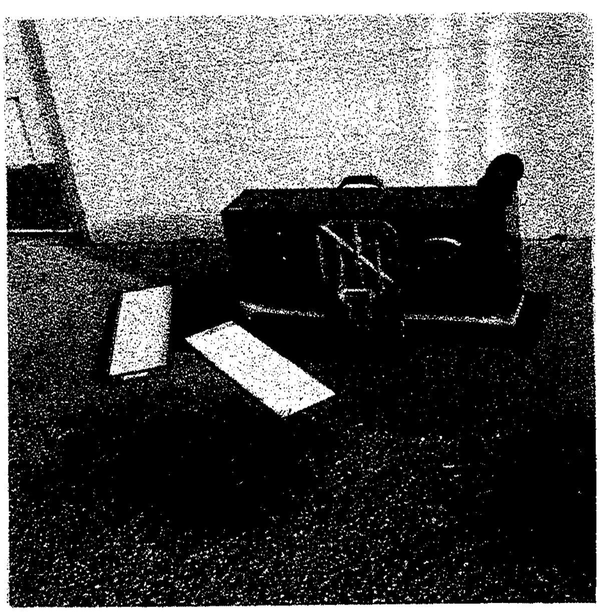

Figure 2. Hunter Night-Visibility Meter

Traffic paints are rough and granular, and for the geometric conditions of night illumination and view usually measure more than unity on the Hunter Meter. Readings of from 2 to 4 on the Hunter Meter are typical of nonreflectorized paints after some use on the road. Good glass-beaded traffic paints used in Illinois measure between 14 and 18.

The Synopal aggregate when tested in the laboratory produced Hunter Meter readings of 12 when dry and 7.3 when wet. A typical limestone aggregate used in Illinois produced readings of 7.5 when dry and 5.4 when wet.

To arrive at some information on meter readings that could be expected from typical pavement surfaces, to which the Synopal aggregate sections might be compared in addition to the control section, ten bituminous concrete pavement surfaces and ten portland cement concrete pavements, all six years old and older, were selected at random for measurement. Results were as follow:

	Hunter Night-Visibility Meter Readings			
	Dry		Wet	
	Range	Average	Range	Average
Ten bituminous concrete pavement surfaces	1.4-2.4	1.8	1.0-1.4	1.1
Ten portland cement concrete pavement surfaces	1.6-2.0	1.8	1.0-1.2	1.1

In testing pavements, the meter was always oriented in the direction of traffic movement and the measurements taken in the wheelpaths and the center of the travel lane.

Averages of reflectance readings taken on the bituminous concrete surfaces of the trial installation after 3 months, 7 months, and 24 months under traffic are shown in Table 4. It will be noted from the table that the addition of Synopal aggregate to the mixture had a favorable influence on light reflectance. It will be noted also that the 50 percent Synopal section showed at two years a light reflectance within the range of that shown for bituminous concrete pavements six years of age, and older, while the reflectances for the 25 percent Synopal section and the control section are somewhat less.

Subjective observations reported by several different people acquainted with the location of the bituminous concrete test sections and who have traveled over the sections under a wide range of weather conditions confirm the results obtained with the Hunter Meter.

It is the intention that additional Hunter Night-Visibility Meter readings be made as time passes.

TABLE 4

HUNTER NIGHT-VISIBILITY METER MEASUREMENTS
BITUMINOUS CONCRETE OVERLAYS

Section	Average Reflectance Field Test				
	3 Months	7 Months		24 Months	
	Dry	Dry	Wet	Dry	Wet
Control (No Synopal)	0.4	0.4	0.3	1.1	0.8
25 Percent Synopal	0.8	1.3	0.4	1.3	0.9
50 Percent Synopal	1.3	1.8	1.1	1.7	1.1

Skid Resistance

A Keystone Mark IV Portable Skid Resistance Tester and the Portland Cement Association skid trailer were used to determine coefficients of friction of the bituminous concrete overlay installations. The Mark IV is a two-wheel portable tester with a trailing rectangular rubber slider as shown in Figure 3. It is pushed along a wetted pavement surface at uniform walking speed in the direction of traffic with the trailing edge of the rubber slider pressing on the pavement.

The resulting friction force displaces the rubber slider, causing the piston to move and create a hydraulic pressure proportional to frictional force.

Figure 3. Keystone Mark IV portable skid resistance tester

Skid tests with the portable tester were performed on wet pavement in the late fall of 1965 and in the early spring of 1966, three months and eight months after the surfaces were opened to traffic. Results of the skid tests made with the portable tester are summarized in Table 5. Because the results of skid tests are dependent to a considerable extent on the testing device that is used, the reported pressure readings should not be looked upon as precise absolute values. However, they can be looked upon as being sufficient to show that no strong differences existed between the skid-resistance properties of the Synopal and control mixtures.

Skid tests with the Portland Cement Association's skid trailer were conducted on October 20, 1966 and on July 26, 1967, 14 months and 23 months after construction. In addition to the trailer itself, the PCA system includes a towing vehicle, a water supply, and instrumentation for measuring the friction drag when the wheels are locked. The trailer utilizes a pair of 7.50 - 14 tires weighted to 1,085 lbs. each to comply with ASTM Designation: E249-64T. Water is forced onto the pavement ahead of the trailer tires by a rotary pump to produce a wet-surface test. Trailer brakes were applied for a distance of approximately 150 feet at a number of random locations in each experimental section while vehicle speed was maintained at 40 mph.

TABLE 5

SUMMARY OF RESULTS OF SKID TESTS OF BITUMINOUS CONCRETE OVERLAY USING PORTABLE TESTER

Travel Lane

	Pressure Readings-Keystone Mark IV Tester - Wet Pavement							
Section	Three Months Age			Eight Months Age			Wheelpath Average	
	OWP	IWP	Center	OWP	IWP	Center	3 Mo.	8 Mo.
Control	33	31	41	36	36	43	32	36
25 Percent Synopal	28	27	33	38	38	44	28	38
50 Percent Synopal	36	35	45	33	33	42	35	33

OWP = Outside wheelpath

IWP = Inside wheelpath

Center = Center of travel lane

The results of the skid tests made with the PCA skid trailer showed only slight differences between the Synopal and control sections up to 23 months age, with the Synopal sections showing slightly higher skid resistances. The results of the skid tests are summarized in Table 6. The friction values are all higher than the coefficient of friction of 0.32 used by AASHO for the computation of the minimum stopping distance for the speed of 40 mph under the wet pavement condition.

TABLE 6

SUMMARY OF RESULTS OF SKID TRAILER TESTS
OF BITUMINOUS CONCRETE OVERLAY

Section	Coefficients of Friction - Skid Trailer - Wet Pavement					
	Passing Lane		Travel Lane		Section Average	
	14 Mo.	23 Mo.	14 Mo.	23 Mo.	14 Mo.	23 Mo.
Control	.38	.48	.40	.35	.39	.41
25 Percent Synopal	.39	.48	.40	.37	.40	.42
50 Percent Synopal	.39	.50	.44	.39	.42	.44

Roughometer Readings

Surface smoothness tests made two months after construction with the Illinois BPR-type roughometer showed readings in the "Very Smooth" category (60 or less) by Illinois standards for all test sections. Twenty-two months after construction, the control section and the 25 percent Synopal sections were still in the "Very Smooth" category, while the 50 percent Synopal sections were in the "Smooth" category (60-75). Results of these tests are reported in Table 7. The inclusion of the Synopal aggregate will be seen to have had no significant initial effect on surface smoothness.

TABLE 7

INITIAL ROUGHOMETER READINGS
BITUMINOUS CONCRETE OVERLAYS

Section	Surface Course Thickness (in.)	Roughness Index: Outside Lane 2 Mo.	Outside Lane 22 Mo.	Inside Lane 2 Mo.	Inside Lane 22 Mo.	Average 2 Mo.	Average 22 Mo.
Control (No Synopal)	1	58	58	56	57	57	58
25 Percent Synopal	1	57	57	55	60	56	58
50 Percent Synopal	1	56	59	58	63	57	61
50 Percent Synopal	1 1/2	58	65	57	64	58	64

Performance

The structural performance of all overlay test sections is satisfactory at 24 months of service as is to be expected at this early stage. Representative views of the test sections at 20 months age are shown in Figures 4 and 5. Typically, reflection cracking has occurred in all sections over the expansion joints spaced at 100-foot intervals in the old reinforced portland cement concrete pavement. A small amount of raveling started at these cracks during the first winter, but nothing was found to indicate a relationship between the raveling and any of the mixtures that were used.

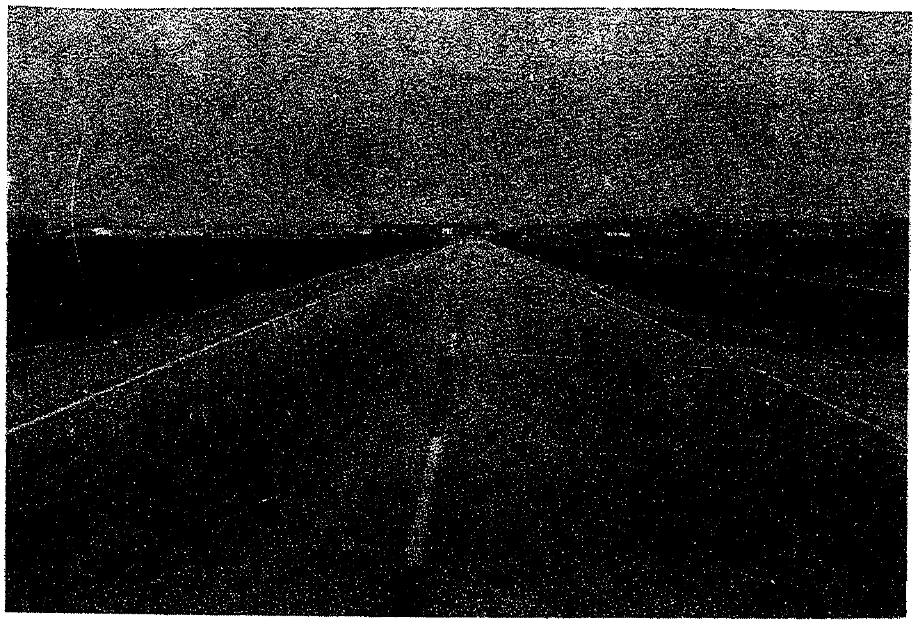

Figure 4. Performance of the 25 percent Synopal section (Livingston County) at 20 months age

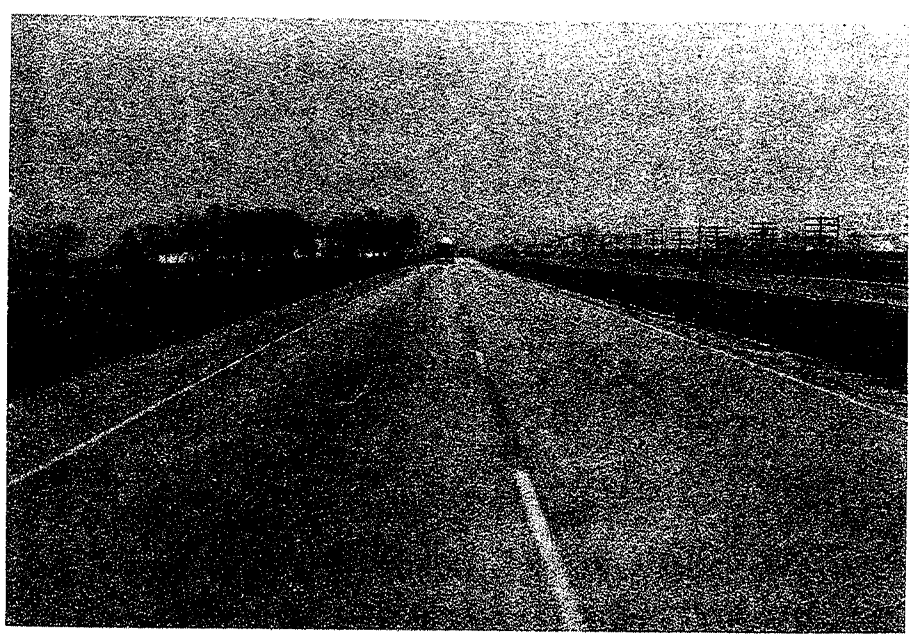

Figure 5. Performance of the 50 percent Synopal section (Livingston County) at 20 months age

SURFACE TREATMENTS

Pavements

Three pavement installations were made to evaluate the properties of Synopal as an aggregate for use in bituminous surface treatments. The locations and dates applications were made are as follow:

(1) FAS Route 583, SA Route 5, Camden Road, Schuyler County (August 17-19, 1965)

(2) FAS Route 455, SA Route 1, north of Route US 24, Rushville, Schuyler County (August 19, 1965)

(3) Routes Illinois 48 and 127, west of Raymond, Montgomery County (August 28, 1965)

The two Schuyler County projects were previously scheduled improvements of light-traffic secondary road surfaces. The Synopal aggregate was substituted for the natural aggregate previously planned for use.

The Montgomery County trial consisted of the application of the surface treatment to several hundred feet of a bituminous concrete surfacing serving primary traffic. The bituminous concrete was not considered to be in need of treatment, and the application was made principally to observe the skid resistance of the treatment during its early stages of curing when minimal tractive resistance would be expected. If it showed a reasonable degree of skid resistance at this early period, the trial was to be extended to a primary signalized intersection. The use of the treatment as a means for improving the tractive resistance of pavements that have worn slippery at such intersections was the prime interest. Because of the impracticability of closing such intersections to traffic more than a few hours, early high skid resistance was deemed important. The treatment showed poor resistance to skidding during the first hours and days following application, and plans for its use to improve tractive resistance at signalized intersections were abandoned.

All surface treatments were applied by Day Labor forces of the Illinois Division of Highways.

Construction Procedure

The Camden Road section in Schuyler County selected for test consisted of a two-mile length of 10-foot-width bituminous treated flexible base pavement adjoining a single-lane concrete pavement as shown in Figures 6 and 7. A number of subsections were established on this pavement as follow:

Section	Synopal Size	Synopal Amount (lbs. per sq. yd.)	Asphalt Type	Asphalt Amount (gal. per sq. yd.)
A	8-12 mm.	15	PA 1	0.20
B	8-12 mm.	15	PA 1	0.25
C	8-12 mm.	15	MC 5	0.20
D	5-8 mm.	10 1/2	MC 5	0.20

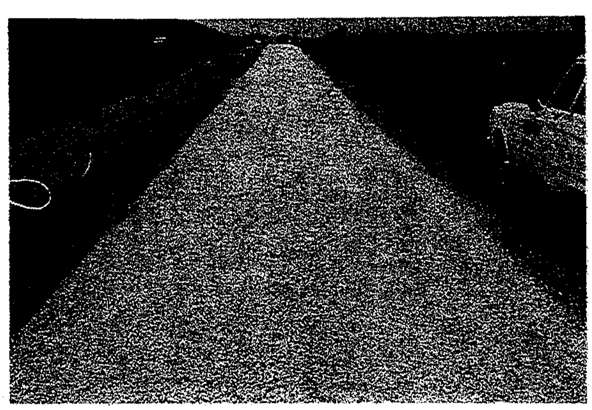

Figure 6. Newly placed 8-12 mm. size Synopal aggregate seal coat (Schuyler County)

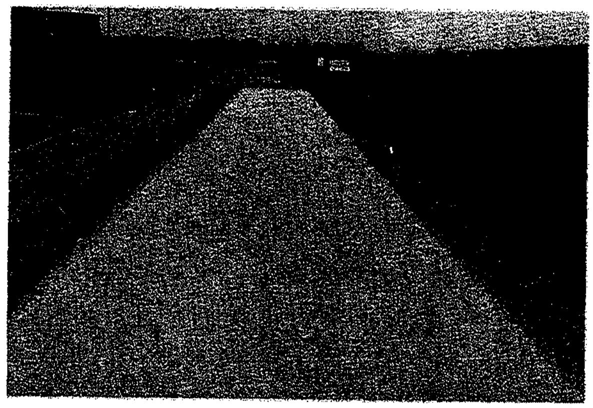

Figure 7. Newly placed 5-8 mm. size Synopal aggregate seal coat (Schuyler County)

The Rushville test section consisted of a surface treatment with 0.15 gal. per sq. yd. of MC 5 asphalt followed by an application of 5-8 mm. size Synopal aggregate at the rate of 10 1/2 lbs. per sq. yd. As in the case of the Camden Road section, the original pavement was a bituminous-treated flexible base adjoining a single-lane concrete pavement. This section is about 0.9 miles long and has a bituminous-treated lane width of about 9 feet.

The test section in Montgomery County consisted of 425 feet of two 11-foot lanes of bituminous-concrete resurfacing of an old portland cement concrete pavement. In this section, 5-8 mm. Synopal aggregate was applied at a rate of 11 lbs. per sq. yd. over MC 5 applied at rates of 0.15 and 0.20 gal. per sq. yd.

The pavement surfaces were reasonably free of dirt and dust at the time of the seal coat treatments. Asphaltic materials were applied with a pressure distributor. The Synopal aggregate was placed with an aggregate spreader immediately after application of the asphalts. Rolling with a pneumatic-tired roller followed the aggregate application. All work was done in warm, dry weather during the last half of August.

Because of its relatively low specific gravity, the weights of Synopal used per sq. yd. were noticeably lower than required with conventional aggregates.

In accordance with a recommendation of the supplier of the Synopal aggregate, an antistripping agent sold under the trade name of "No-Strip" was thoroughly mixed with the asphalts used in all of the surface treatments in an amount of one percent of the asphalt.

Night Visibility

Night-visibility tests using the Hunter Night-Visibility Meter were conducted one month and seven months after construction on the seal-coat test pavements in the same manner as described previously for the bituminous-concrete overlays. Average readings that were obtained are summarized in Table 8. Also shown in Table 8 are the results of readings made on the surface-treated shoulders that were included in the experimentation and which will be described later.

The readings summarized in Table 8 are only those which were taken in areas where the Synopal aggregate remained present in reasonable amount. Unfortunately, considerable loss of the aggregate under traffic occurred in many areas, and no further readings were made with the Hunter Meter.

It will be recalled that Hunter Meter readings made in the laboratory on the Synopal aggregate alone were 12 when dry and 7.3 when wet. Similar readings taken on the typical limestone aggregate used in the shoulder experiment to be described later and mentioned in Table 8 were 7.5 when dry and 5.4 when wet.

It will be noted that the Synopal aggregate surface treatments showed considerably better light reflectivity than any bituminous concretes or portland cement concretes tested; also a light reflectivity somewhat better than that of the surface treatment containing what was considered to be a typical natural limestone aggregate.

TABLE 8

HUNTER NIGHT-VISIBILITY METER MEASUREMENTS
BITUMINOUS SURFACE TREATMENTS

Location	Average Reflectance Field Test: 1 Month Dry	7 Months Dry	7 Months Wet	Construction Detail
Camden Road, Schuyler County	11.3	9.5	7.9	North Lane PA 1, 0.20 gal/sq yd 8-12 mm Synopal at 15 lb/sq yd
	11.3	8.1	6.8	PA 1, 0.25 gal/sq yd 8-12 mm Synopal at 15 lb/sq yd
	11.0	7.0	6.3	MC 5, 0.20 gal/sq yd 8-12 mm Synopal at 15 lb/sq yd
	9.7	7.4	5.3	MC 5, 0.20 gal/sq yd 5-8 mm Synopal at 10.5 lb/sq yd
Near Rushville, Schuyler County	9.4	7.5	5.8	East Lane MC 5, 0.15 gal/sq yd 5-8 mm Synopal at 10.5 lb/sq yd
Route Ill. 127-48 W. of Raymond, Montgomery County	9.0	8.5	-	South Lane MC 5, 0.20 gal/sq yd 5-8 mm Synopal at 11 lb/sq yd
	8.5	7.8	-	MC 5, 0.15 gal/sq yd 5-8 mm Synopal at 11 lb/sq yd
Route Ill. 29, W. of Rochester, Sangamon County	6.6	6.8	5.4	South Shoulder PA 1, 0.20 gal/sq yd Limestone - 3/8 in. at 20 lb/sq yd - CONTROL SECTION
	10.8	6.4	6.6	PA 1, 0.20 gal/sq yd 8-12 mm Synopal at 13 lb/sq yd
	10.7	6.7	5.9	North Shoulder PA 1, 0.15 gal/sq yd 8-12 mm Synopal at 15 lb/sq yd

Skid Resistance

Attempts that were made to measure the skid resistance of the surface treatments with the Keystone Mark IV Tester were unsuccessful because of limitations of the tester. Subjective tests made by braking passenger vehicles on the surfaces during the first months after treatment did not indicate any special qualities of tractive resistance. However, braking invariably resulted in loosening and removal of the aggregate from the asphalt binder, and the tractive resistance of the aggregate itself was not a major factor.

Fifteen months after the surface treatment of the section on Route Illinois 127-48, the PCA skid trailer was used to determine the coefficient of friction of the treated surface. With the speed of the towing vehicle maintained at 40 mph, the coefficient of friction obtained was 0.51. Somewhat lower values were obtained in tests conducted at about the same time on some surface treatments containing natural aggregates.

Performance

On the Camden Road section, and on the shorter section near Rushville, after seven months of service, about 1/5 to 1/2 of the Synopal aggregate had become loosened and much of it had been worked to the edges of the pavement by traffic. The aggregate appears to be adhering best in the wheelpaths. Little difference between the various test sections was noted, except perhaps that on the Camden Road, where both 5-8 mm. and 8-12 mm. sizes of Synopal were used, the 8-12 mm. size suffered the greater loss as can be seen by comparing Figures 8 and 9.

Aggregate coverage of the bituminous concrete pavement on Route Illinois 127-48 has remained fair after 23 months of service, except for a few small areas where the aggregate evidently was removed by snowplows or farm equipment as shown in Figure 10.

Figure 8. Performance of 8-12 mm. size Synopal aggregate seal coat (Schuyler County) at 7 months age

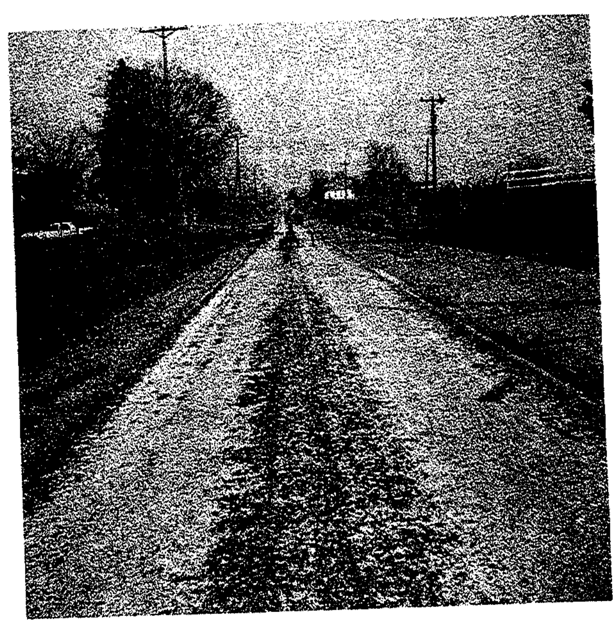

Figure 9. Performance of 5-8 mm. size Synopal aggregate seal coat (Schuyler County) at 7 months age

Figure 10. Performance of 5-8 mm. size Synopal aggregate seal coat (Montgomery County) at 23 months age

Shoulders

One shoulder surface-treatment section was established to evaluate the Synopal aggregate as a means for defining shoulder areas where both pavement and shoulders are of bituminous construction. The section selected for this study was a newly constructed pavement and shoulder combination built on Route Illinois 29 (SBI Route 24, Section 6R, 8R-1, and (6,8)RS-1, Sangamon County) between Rochester and Springfield. This section consists of 2.7 miles of bituminous pavement and paved shoulders in which the shoulder is 10 feet wide on one side of the pavement and 4 feet wide on the other side. The Synopal aggregate was applied to the total length of 10-foot shoulder and to a portion of the 4-foot shoulder. A commonly used limestone aggregate was applied to the remaining length of 4-foot shoulder for comparison. The 8-12 mm. Synopal aggregate was used in this phase of the study. The limestone aggregate was a typical seal-coat chip passing the 3/8-inch sieve and mostly retained on the No. 4 sieve.

The larger-size Synopal aggregate was used in this application in the belief that it might have somewhat better "rumble" characteristics to warn motorists leaving the pavement.

Construction Procedure

Application procedures used in the shoulder treatments were the same as described previously for the pavement surface treatments. The Synopal aggregate treatment included applications of 13 and 15 lbs. per sq. yd. over PA-1 asphalt applications of 0.15, 0.20, and 0.25 gal. per sq. yd. The limestone chips were applied at a rate of 20 lbs. per sq. yd. over PA-1 asphalt applied at a rate of 0.20 gal. per sq. yd. The difference in the specific gravities of the Synopal aggregate and the limestone aggregate is responsible for the difference in the weights applied; coverage was about the same.

As mentioned previously, an antistripping agent was mixed with the asphalts of all surface treatments prior to application.

Night Visibility

Hunter Night-Visibility Meter test results for the shoulder treatments are summarized in Table 8, and were discussed briefly along with the discussion of the readings taken on the surface-treated pavements. The light reflectance of the Synopal aggregate was slightly better than that of the limestone. Both materials have a good delineating effect, and this treatment of shoulders appears to have some potential as a safety feature, providing a reasonably permanent treatment can be devised.

Skid Resistance

As mentioned previously, the Keystone Mark IV Tester did not prove to be a suitable device for testing the skid resistance of the surface treatments. As with the pavement surface treatments, braking of vehicles on the shoulder treatments resulted in loosening and removing aggregate from the asphalt binder.

Performance

The Synopal aggregate did not adhere well in the shoulder treatment, and about 1/4 was found to be loose and removed after seven months as shown in Figure 11. Adherence of the limestone chips, on the other hand, has been very good as shown in Figure 12. The difference in adherence is considered to be influenced by the aggregate material, but the exact nature of the influence was not determinable.

Figure 11. Performance of 8-12 mm. size Synopal aggregate seal coat (Sangamon County at 7 months age

Figure 12. Performance of limestone chip seal coat (Sangamon County) at 7 months age

SUMMARY OF FINDINGS

The Synopal aggregate was tested in the laboratory and in the field by the Illinois Division of Highways to evaluate its merits, particularly its light-reflectant and skid-resistant characteristics, in the following uses:

(1) as an aggregate substituted for part of the coarse aggregate in bituminous concrete surface course mixtures.

(2) as a bituminous seal-coat aggregate for surface treatment

   (a) of low-traffic roads

   (b) of primary highway signalized intersections of substandard skid-resistance

   (c) of bituminous-paved shoulders adjoining bituminous-concrete pavements to improve shoulder delineation.

In the laboratory, major tests performed on the Synopal aggregate, in addition to the usual gradation test, were the Los Angeles abrasion test and the sodium sulphate soundness test. The material showed relatively good resistance in both of these tests. The results of all tests were well within the limits prescribed by the Illinois Division of Highways for coarse aggregates for bituminous-concrete and surface-treatment construction.

In the field, Synopal aggregate showed the following characteristics in up to 24 months and through two winters of service:

(1) <u>Night visibility</u>

When tested with a Hunter Night-Visibility Meter at age 3, 7, and 24 months:

(a) Substitution of Synopal aggregate for up to 50 percent of a limestone aggregate in a bituminous concrete mixture produced some improvement in the night visibility under both wet and dry conditions in relation to the amount of Synopal aggregate used.

(b) Night-visibility recordings for bituminous surface treatments having Synopal aggregate and for a treatment having a natural limestone aggregate showed better night visibility for the Synopal aggregate.

(2) <u>Skid resistance</u>

The skid resistances of the bituminous concretes containing Synopal aggregate and of a control section were measured with the Portland Cement Association skid trailer and with a Keystone Mark IV portable tester. The skid trailer was used also to test one surface-treatment installation. The portable tester was found to be not suitable for measurement on surface treatments. Based on determinations 15 months and 23 months after construction:

(a) The bituminous concretes with and without the Synopal aggregate were indicated to have relatively high skid-resistances of the same order, with the Synopal aggregate sections usually showing very slightly better skid resistances.

(b) The surface treatment with Synopal aggregate at Route Illinois 127-48 showed a coefficient of friction higher than those of the bituminous concrete overlays with and without the Synopal aggregate mentioned above, and also somewhat higher than several surface treatments containing natural aggregates tested at the same time.

(3) Structural performance

No significant structural deterioration occurred in any of the bituminous concrete sections either with or without the Synopal aggregate at 24 months of service.

The Synopal aggregate showed mostly poor performance in adhering to the bituminous binder materials in the surface treatments. The lack of good adherence is believed to have resulted from some characteristic of the aggregate, but this was not established in the testing.

The relatively long period of curing required for bituminous surface treatments was not encouraging to the use of this type of construction to improve skid resistance at high-traffic-volume intersections regardless of the kind of aggregate used.

(4) Color contrast

A subjective evaluation of the color contrast offered through the use of either the Synopal aggregate or limestone aggregate in bituminous surface treatment of shoulders adjacent to a bituminous concrete pavement indicated a potential for this type of treatment as a delineation feature.