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PINHOLING IN GUARDKOTE® 140

by

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ABSTRACT

A GUARDKOTE® 140 application made in 1960 on the Ohio Street Bridge in Chicago was observed to have pinholes and was not water-tight. A laboratory program lasting over a period of approximately nine months was conducted to determine the causes and arrive at ways to prevent the recurrence of this condition. Laboratory findings indicated that pinholing was caused by capillary action of the liquid GUARDKOTE binder when excess amounts of certain types of surfacing grits are used. Several methods for correcting this condition were found, but a second layer of GUARDKOTE binder was used to repair and seal the Ohio Street Bridge. Additional laboratory findings indicated that pinholes could be eliminated on acid-etched portland cement concrete by applying GUARDKOTE 140 at a minimum of 2.5 pounds per square yard and using 12-30 and 14-24 mesh emery grit.

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INTRODUCTION AND SUMMARY

During the 1960 paving season, a GUARDKOTE® 140 application was made on the concrete-filled steel grating deck of the Ohio Street Bridge, Chicago, Illinois. Rust stains were observed on the GUARDKOTE applied over the steel grating soon after the newly coated deck was exposed to rainfall. This indicated that water was going through the coating. To seal the coating, it was necessary to apply another coat of GUARDKOTE 140 on the entire deck. A laboratory investigation was undertaken to determine the cause of and remedy for this condition.

Preliminary laboratory investigations were intended mainly to define the parameters and obtain clues concerning the nature of this problem. At first, GUARDKOTE 140 was applied without grit, in binder rates of one to three pounds per square yard. Still varying binder rates, additives such as thickeners (Cab-O-Sil mainly) and several flow control agents were then incorporated into the binder system. In trying many combinations of these variables on glass and steel surfaces, it was concluded that the pinholing problem involved something besides surface wetting.

Soon it became obvious that pinholing was caused by capillary action of the liquid GUARDKOTE binder when excess amounts of certain types of surfacing grits are used. In the case of the Ohio Street Bridge, however, further difficulty was encountered in wetting the surfaces of the steel grating. Mention should be made that, although concrete and some steel surfaces are involved in this problem, glass surfaces were used in the preliminary work to facilitate visual evaluation of the cured systems. In addition, since glass and steel are more difficult to wet than concrete, with EPON Resin systems, it was felt that any satisfactory results obtained on these hard to wet surfaces would hold on concrete.

After gathering this background information, it was discovered that various grit sizes and amounts of grit applied influenced the amount of pinholing. The addition of Cab-O-Sil and the thickness of binder material also were found to be important factors. Although laboratory efforts were made to eliminate pinholing without altering the recommended grit size (8-30 mesh at the time) or the basic binder formulation, it was not possible. Grit of the recommended size, especially when applied in excess, seemed to "pull" the GUARDKOTE binder away from the surface being treated, distributing the binder unevenly and causing pinholing.

At this point it was decided to approach the problem mainly with regard to grit size. Limited work was still done incorporating tackifiers, anti-stripping agents, and mineral fillers into the binder system, but most of the effort was devoted toward finding a suitable grit size to eliminate the problem. Grit systems of many gradation levels were investigated so that chances of arriving at several successful systems were increased.

Summing up at this point then, we find that pinholing is partially or completely eliminated by the following techniques:

1. Use of finer aggregate
2. Application of a second binder layer
3. Application of no excess aggregate
4. Addition of Cab-O-Sil to the binder (which increases the viscosity)
5. Use of thicker layers of binder
6. Delay the application of aggregate

Of all these methods; the grit size approach still looked most attractive. Application of a second binder layer (as done on Ohio Street) was felt to be too expensive. Equipment for applying only the required amount of grit was not available at the time. The addition of Cab-O-Sil and the increase in viscosity it would bring might cause difficulties in pumping the binder from automatic dispensing equipment. The use of thicker layers of binder would make the cost prohibitive. And finally, delaying the application of grit would increase the chances of hardening before sufficient grit could be applied.

The final segment of testing took place on concrete and metal surfaces. GUARDKOTE grit layers were applied to concrete and metal surfaces. After curing, the GUARDKOTE surfaces were saturated with acid solutions. The immediate appearance of bubbling on the GUARDKOTE surfaces indicated a reaction of the acid with the concrete or metal substrate and, hence, the presence of pinholes. The results of these tests showed that on acid etched portland cement concrete GUARDKOTE 140 and 120, applied at 2.5 pounds per square yard or greater using 12-30 mesh and 14-24 mesh emery grit, was free of pinholes. It should be pointed out that these results were obtained on, and apply only to, acid etched portland cement concrete surfaces. In addition, the information was obtained strictly on a laboratory basis and, therefore, we were limited to some extent in simulating precise field conditions.

EXPERIMENTAL

The experimental phases of the study were divided into two areas. The first was of a preliminary nature where the investigation was intended mainly to define the parameters, obtain background information, and gather clues regarding the fundamental aspects of this problem. In other words, what causes pinholing in GUARDKOTE 140 grit-surfaced overlays? The second phase dealt with determining corrective measure for the Ohio Street Bridge job and for future GUARDKOTE installations.

Defining the Problem

In gathering background information on the problem, the first step was to reproduce, in the laboratory, the conditions existing on the Ohio Street Bridge. Portland cement concrete was cast in two wooden boxes. Before the concrete hardened, ten 4" x 1" x 1/4" pieces of steel were embedded in the concrete so that approximately 1/32" of the 4" x 1/4" steel surface was exposed above the level of the concrete. The concrete was then allowed to cure for seven days. No steel was embedded in the concrete in the other box. The concrete in both boxes was etched with a 15% solution of hydrochloric acid. Over each steel bar embedded in concrete and over the concrete in the second wooden box, various GUARDKOTE 140 or GUARDKOTE 140-type systems were placed at 3 pounds per square yard. The following tables summarize the systems installed on the concrete in each wooden box. The materials used in all of the subsequent studies are identified in the glossary.

TABLE I

Steel-Embedded Concrete

System	Aggregate (in excess)	Remarks
1	8-20 mesh emery	-
2	6-12 mesh aluminum oxide	-
3	8-35 mesh emery	-
4	8-50 mesh emery	-
5	12-30 mesh aluminum oxide	-
6	8-35 mesh emery	3% emery dust added to aggregate
7	8-35 mesh emery	5% emery dust added to aggregate
8	8-35 mesh emery	1% Cab-O-Sil added to binder
9	8-35 mesh emery	2% Cab-O-Sil added to binder
10	8-35 mesh emery	a)

a) The resin component was 44.5 pbw EPON 828, 4.5 pbw pine oil, and 1.0 pbw phenol instead of GUARDKOTE 140A

TABLE II

Concrete Only

System	Aggregate (in excess)	Remarks
1	8-30 mesh emery	same as Ohio Street Bridge
2	6-12 mesh emery	-
3	12-30 mesh aluminum oxide	-
4	30-80 mesh emery	-

After curing for 24 hours at 77°F, the various resinous overlays were covered with water and kept wet during the daytime hours from Monday through Friday of each week. The test was conducted for 108 days and, during this time, any changes in appearance and any irregularities were noted.

The behavior of GUARDKOTE 140 binders on various surfaces was investigated next. Although the problem of pinholing originated primarily on concrete and steel surfaces, most of the preliminary work was carried out on glass and steel surfaces. The use of glass at this point of the study was more convenient and made visual determination of irregularities much easier. GUARDKOTE 140 and similar binder systems were applied to 4" x 8" solvent-wiped steel and glass panels at rates of one and three pounds per square yard. Cab-O-Sil and various flow control agents were added to the binder systems at different concentrations. The various additives incorporated into the binder systems were as follows:

Cab-O-Sil
Sag 47
SR-82
Advawet 82
Beetle 216-8
Nuosperse 657
Advawet 10
DC-200
Antifoam A

After studying the behavior of binders with various additives, GUARDKOTE 140 and similar systems, with surfacing aggregate, were applied on 4" x 8" glass panels. The binders were applied at 3 pounds per square yard, and the following table summarizes the systems investigated.

TABLE III

Systems of GUARDKOTE 140 and Aggregate Applied on Glass

System	Aggregate (in excess)	Remarks
1	8-20 mesh emery	-
2	6-12 mesh aluminum oxide	-
3	8-35 mesh emery	-
4	8-50 mesh emery	-
5	12-30 mesh aluminum oxide	-
6	8-35 mesh emery	3% emery dust added to aggregate
7	8-20 mesh emery	5% emery dust added to aggregate
8	8-20 mesh emery	1% Cab-O-Sil added to binder
9	8-20 mesh emery	2% Cab-O-Sil added to binder
10	8-20 mesh emery	a)
11	8-20 mesh emery	Emery rolled with an iron cylinder
12	8-20 mesh emery	Emery premixed with binder 3pbw to 1pbw
13	10-30 mesh quartz	-
14	none	Binder only
15	none	0.5% Cab-O-Sil added to binder
16	none	1% Cab-O-Sil added to binder
17	none	2% Cab-O-Sil added to binder

a) The resin component was 44.5 pbw EPON 828, 4.5 pbw pine oil, and 1.0 pbw phenol instead of GUARDKOTE 140A

When the overlays on glass had cured, the excess aggregate was removed and the coatings examined for pinholes and voids.

Determining Corrective Measures

In determining the corrective measures for pinholing, the first order of business was repairing the Ohio Street Bridge job. In order to repair the bridge, it was felt necessary to seal all of the pinholes with an overcoat of GUARDKOTE 140 binder. To penetrate these pinholes, a low viscosity system was needed and, to fill this requirement, GUARDKOTE 140 was diluted with amounts of xylene totaling 5, 10, and 20%. The three systems were tested for viscosity, handling characteristics, cure rate, and hardness after curing.

Next, attempts were made to discover ways of eliminating pinholing in future GUARDKOTE jobs. Studies were conducted on several phases of grit and binder application, the possibility of employing heat to the system, and finally the actual quantitative determination of pinholes on GUARDKOTE surfaces.

In studying grit application, various particle sizes were investigated, the amounts of grit added were varied, and time delays were incorporated between the spreading of the binder and the addition of grit. The GUARDKOTE 140 binder was modified with flow modifiers and solid fillers. Increases in binder viscosity were made by adding Cab-O-Sil. The binder was also studied over a wide range of application rates (thicknesses). The following lists give the various solid fillers and flow modifiers used in the study.

Solid Fillers

Wollastonite P-1	MCG-1
Slate Flour	Microcel E
Suspenso	Celite 1655
Asbestos 7TF1	Bentone 27

Flow Modifiers

Sag 47	SF-69	Pluronic L-61
AYAF	Triethylene glycol	Antisag 7
Ethyl alcohol	Antifoam A	Duomeen S
Furfuryl alcohol	Tween 20	Duomeen O
Triethylamine	SR-82	Duomeen C residue
EPON Curing Agent V-40	Span 80	Duomeen C and S residue
n-Hexane	Aerosol C-61	

In addition, heat was administered to the aggregate, the surfaces being treated, and the GUARDKOTE 140 binder.

Final testing took place on concrete and steel surfaces. GUARDKOTE 120 and 140 were applied to concrete castings in wide-mouthed jars and on steel 4" x 8" panels. After the GUARDKOTE cured for 24 hours at 77°F, the excess grit was removed and the GUARDKOTE was ready for testing. The testing was carried out by saturating the GUARDKOTE on both types of surface with acid solutions, 32% hydrochloric for the concrete substrate and for the steel a solution made up of equal volumes of concentrated hydrochloric and nitric acids. The immediate appearance of bubbling on the GUARDKOTE surfaces indicated a reaction between the acid and the concrete or metal substrate and, hence, the presence of pinholes. The tests were conducted at different GUARDKOTE binder rates, with grit of various particle sizes, with and without Cab-O-Sil, and with and without acid etching the concrete surfaces. All tests with the metal panels were conducted on solvent wiped steel.

RESULTS AND DISCUSSION

As mentioned previously, the study was divided into two areas. One, defining the problem and obtaining background information and clues regarding the fundamentals of pinholing. The second area dealt with determining corrective measures for the Ohio Street Bridge job and for future GUARDKOTE installations.

Defining the Problem

The GUARDKOTE systems covered with water served to reproduce the conditions observed on the Ohio Street Bridge. When the liquid GUARDKOTE 140 binder was applied to the acid-etched concrete and steel bars in the first box, the binder was observed to "crawl" off the steel bars leaving little or no binder on the steel. The GUARDKOTE wetted the concrete in both boxes, however in the normal manner.

Rust stains, similar to those observed on the Ohio Street Bridge, were seen above the steel bars coated with GUARDKOTE 140 and five different types of aggregate after 35 days. All five systems (listed below and also in Table I) were GUARDKOTE 140 placed at three pounds per square yard using the following aggregates:

System	Aggregate
1	8-20 mesh emery
2	6-12 mesh aluminum oxide
3	8-35 mesh emery
6	8-35 mesh emery (3% emery dust added to aggregate)
7	8-35 mesh emery (5% emery dust added to aggregate)

The three types of 8-35 mesh emery most closely simulated the 8-30 mesh emery (unavailable at the time of testing) used on Ohio Street. The grit used on the job had a higher dust content than is normally observed, but it apparently had little effect on causing or eliminating pinholes in grit surfaced GUARDKOTE since the dust-free 8-35 mesh emery coating also showed the presence of pinholes. After 108 days the rust stains still persisted over the same five overlays, but did not appear over the other systems (systems 4, 5, 8, 9, and 10). See Table I under the Experimental Section for a complete list of these systems.

The 4 systems applied over acid-etched concrete (listed in Table II) and also covered with water for 108 days showed no signs of rusting throughout the entire duration of testing. One of the four systems was GUARDKOTE 140 at 3 pounds per square yard with 8-30 mesh emery taken from the Ohio Street Bridge job site. These systems appear in Table II under the Experimental Section.

In order to get closer to the individual aspects of the problem, the next step was to investigate the GUARDKOTE 140 binder separately (without aggregate). Binder systems containing 1% Cab-O-Sil were compared to systems not containing Cab-O-Sil in regard to crawling before curing and to the formation of voids and/or pinholes while curing. The GUARDKOTE 140 was applied on solvent-wiped steel and glass surfaces at rates of 1 and 3 pounds per square yard. The tests showed that crawling occurred only with systems applied at 1 pound per square yard containing no Cab-O-Sil regardless of the type of surface treated. Systems containing 1% Cab-O-Sil, on both surfaces, and at both rates did not crawl. After curing, voids and pinholes were evident not only where crawling occurred on the uncured binder but also on both steel and concrete surfaces, at 1 and 3 pounds per square yard, and containing Cab-O-Sil.

This showed that while Cab-O-Sil eliminated crawling on steel and glass surfaces, it did not eliminate pinholes, and that their formation was probably related more to the entrapment of air beneath the surface of the binder layer.

Eight different flow control agents were blended with GUARDKOTE 140 binder. All were added to the binder at levels of 0.5, 1, and 2%. They are as follows:

Sag 47	Nuosperse 657
SR-82	Advawet 10
Advawet 82	DC-200
Beetle 216-8	Antifoam A

The GUARDKOTE 140 modified with the flow control agents was applied to glass and steel surfaces at 1 and 3 pounds per square yard. None of these, except for Sag 47, were satisfactory in eliminating pinholing caused by entrapped air after curing regardless of surface or rate of coverage. The Sag 47 completely eliminated this type of pinholing when used at 0.5, 1, and 2% on steel and concrete, and at 1 and 3 pounds per square yard. Additional trials showed that on both types of surfaces and, at 3 pounds per square yard, 0.1% and 0.2% of Sag 47 would also eliminate pinholing in cured binder coatings. The elimination of pinholes using Sag 47 was accomplished only with GUARDKOTE 140 not surfaced with grit. It is seen in a later experiment that, even in the presence of Cab-O-Sil (later found to be helpful in eliminating pinholes), Sag 47 does not aid in eliminating pinholes in aggregate-surfaced GUARDKOTE 140.

The study was next directed toward examining GUARDKOTE 140 and similar systems with different surfacing aggregates. The systems were applied on 4" x 8" glass panels at 3 pounds per square yard, and with an excess of aggregate. To test previous findings, four systems were not seeded with aggregate and, to three of these, Cab-O-Sil was added in various concentrations. A complete list of binder and aggregate systems applied on glass appears in Table III in the Experimental Section.

A total of 17 systems was tested, 13 with grit and 4 without. The four panels containing GUARDKOTE 140 without grit showed the usual fine pinholes, earlier suspected of being trapped air. When examined by holding the panel between a light source and the viewer, these fine pinholes did not give evidence of transmitting light through the GUARDKOTE coating. The 13 samples containing grit, however, showed different results. When held up to the light, the viewer was able to see transmitted light through larger and more numerous pinholes, apparently caused by the addition of the surfacing aggregate.

Determining Corrective Measures

At the time of early investigations concerning the pinholing problem, it was necessary to arrive at a suitable way of repairing the Ohio Street Bridge job. It was decided to use a xylene-diluted GUARDKOTE 140 binder system as an overcoat on top of the original overlay. Three xylene-diluted GUARDKOTE 140 systems were investigated. The results of a preliminary study follow.

Xylene concentration, % added	5	10	20
Viscosity, cps, at 77°F	410	180	40
Shore D, 24 hrs at 77°F[a)]	21-15	15-12	9-6
Shore D, 24 hrs at 77°F + 2 hrs at 180°F	35-22	30-19	liquid separation

a) The hardness readings are the initial values and the value after 10 seconds of instrument-sample contact.

The system to which 20% xylene was added was chosen for the job. The very low viscosity (40 centipoises) made it an ideal candidate for penetrating and sealing the pinholes on the bridge. This composition weighed 9.15 pounds per gallon and, when applied on top of cured GUARDKOTE 140 out-of-doors, it cured overnight. Coverage of this out-of-doors test patch was 1.16 pounds per square yard. The system was later applied with large paint rollers to the 1800 square yard GUARDKOTE 140 overlay on the Ohio Street Bridge at a rate of 1.30 pounds per square yard. The job was completed in one day by 7 men during October, 1960.

Since the preliminary experiments gave a fairly strong indication that the aggregate was responsible for pinholing, this phase of the operation was studied at considerable length. First, an experiment incorporating time delays between binder spreading and grit addition was carried out. GUARDKOTE 140 was applied on 4" x 8" glass panels at 3 pounds per square yard. Emery (8-20 mesh) was applied in excess after a series of time delays. The results obtained are as follows:

Time of Grit Application (minutes)	Results[1)]
0	pinholes
15	pinholes
30	pinholes
45	pinholes
60	pinholes
75	pinholes
90	no pinholes
120	no pinholes

At some point between 75 and 90 minutes after spreading the binder (at 77°F), 8-20 mesh emery can be applied in excess to a 3 pound per square yard coating of GUARDKOTE 140 without inducing pinholing. After this length of time the GUARDKOTE has advanced considerably in cure and bodied a great deal. This suggested that higher viscosity binder systems would not show pinholing when an excess of grit was added.

Again, GUARDKOTE 140 was applied on 4" x 8" glass panels, but this time in a study involving a variation in the quantities of surfacing grit added. The binder was applied at 3 pounds per square yard and 8-20 mesh emery was used as the surfacing aggregate. The results of this study follow.

1) In this experiment and in all subsequent determinations of this type the glass panels were held up to a source of light and visually evaluated for the presence or absence of pinholes. If any light whatsoever shone through the panel, the system was not pinhole free and, therefore, not satisfactory.

Aggregate Applied (lb/square yard)	Aggregate Retained in Binder (%)	Excess	Results
1.48	100.00	no	no pinholing
3.52	100.00	no	no pinholing
4.68	100.00	no	no pinholing
6.88	100.00	no	no pinholing
6.96	100.00	no	no pinholing
8.36	100.00	no	no pinholing
9.00	95.10	yes	pinholing
10.04	85.96	yes	pinholing
11.00	85.60	yes	pinholing
12.08	85.40	yes	pinholing
12.68	85.42	yes	pinholing
17.08	65.46	yes	pinholing
22.72	51.94	yes	pinholing
40.08	29.89	yes	pinholing

From the results, indications are clear that as long as no excess aggregate is added, pinholing does not occur. As soon as a slight amount of excess grit was added, pinholes started to appear. This is seen at the point where aggregate was added at 9 pounds per square yard and of that quantity, 95.10% was retained by the resinous binder.

The next step was to examine a wide range of aggregate particle sizes. Also included in the study were different types of grit applied in excess and binder systems applied at different rates of coverage. The study was carried out entirely on 4" x 8" glass panels and the results of the aggregate particle size study appear in Table IV of the appendix. Of the 302 different systems investigated, 30 produced pinhole-free GUARDKOTE 140 overlays. A summary of the mesh breakdowns of these mixtures appears in Table V.

In examining these results, it can be seen that, in general, more coarse particles of aggregate can be tolerated in applications of 3 pounds per square yard than in the 2 pound applications. Again looking at Table V, it is seen that most of the aggregate in these successful systems fall within the 20-60 mesh range. With two exceptions, however, the overall mesh range of the successful systems extends from 16 to 120. Individually, most of the synthetic aggregate mixes are quite irregular and probably would not be commercially available. The values could, however, be used as a guide in selecting similar gradation types that are commercially available. System 53 shows that in spite of the presence of coarse 8 and 10 mesh particles, there is a wide enough gradation of particles in the fine range to eliminate pinholing. Another significant point is the fact that the coarsest single particle size giving a pinhole free overlay is 35 mesh (system 18).

In studying the binder portion of the system, the first step taken was an investigation of coverage rates. GUARDKOTE 140 was applied to glass at 1, 2, 3, 4, 5, 6, and 7 pounds per square yard and surfaced with an excess of 8-20 mesh emery. Inspection of the cured overlays showed a decrease in pinholes as the rate of coverage increased, but only at 7 pounds per square yard did a pinhole-free coating result.

From the experiment where the application of aggregate was delayed for various periods of time, it was felt that increasing the binder viscosity might help eliminate pinholing. Cab-O-Sil, in concentrations of 1, 1.5, 2, 2.5, 3, and 3.5% was added to GUARDKOTE 140. The thickened binder was applied to glass at 3 pounds per square yard and surfaced with an excess of 8-20 mesh emery. Pinholes were observed at concentrations of 2% and lower of Cab-O-Sil. At 2.5% and higher, no pinholes were seen.

An attempt was made to eliminate pinholing by using a combination of Cab-O-Sil and Sag 47 in the GUARDKOTE 140 binder. Sag 47 in concentrations of 0.1 and 0.5% and Cab-O-Sil at the 1% level were added to GUARDKOTE 140. The binder was spread on glass at 2 pounds per square yard and surfaced with an excess of 8-20 mesh emery. The method was not effective, however, as pinholes were seen in the cured overlay.

The study of Cab-O-Sil modified GUARDKOTE 140 was taken further and, in so doing, aggregate particle sizes were varied to a greater extent. The systems studied and the results obtained appear in Table VI. Systems 8, 11, 20, 21, 22, 26, 27, 29, 30, 31, 34, 35, 36 and 37 exhibited no pinholing. These are GUARDKOTE 140 systems containing 2% Cab-O-Sil, applied at 2.5 pounds per square yard, and surfaced with an excess of various sizes of emery aggregate. The particle sizes of the fourteen successful systems, for the most part, were in the 20-40 mesh range. The overall range of successful systems extended from 12-60 mesh. When compared to similar mesh range values obtained with systems not containing Cab-O-Sil (20-60 mesh and 16-120 mesh overall), it is seen that the incorporation of Cab-O-Sil makes pinhole free overlays possible using coarser aggregate.

Low concentrations of solid fillers were blended with the GUARDKOTE 140 binder in further attempts to eliminate pinholing. The binder was applied at 2.5 pounds per square yard after blending with the following solid fillers at the 0.5, 1, 2, and 3% levels.

Wollastonite P-1	MCG-1
Slate flour	Microcel E
Suspenso	Celite 1655
Asbestos 7TF1	Bentone 27

Emery aggregate with the following per cent-by-weight mesh breakdown was applied in excess.

U.S. Standard Sieve No.	Mixture A[a)]	Mixture B[b)]
12		6
14	2	18
16	21	25
18	23	18
20	23	15
25	15	9
30	13	7
35	3	2

a) Designated 14-24 mesh emery, American Abrasive Co., Westfield, Mass.
b) Designated 12-30 mesh emery, American Abrasive Co., Westfield, Mass.

This approach apparently has no merit since all of the 64 systems evaluated produced overlays containing pinholes.

A final approach involved adding various flow modifiers and heating the GUARDKOTE 140 binder, the emery aggregate, and the glass surface, to 100°F before application. In all cases the binder was applied at 2.5 pounds per square yard and aggregate having the following gradation was used.

U.S. Standard Sieve No.	% By Weight Retained
14	2
16	21
18	23
20	23
25	15
30	13
35	3

The systems studied and the results obtained appear in Table VII. It is readily seen that the incorporation of these materials at the given concentrations does not prevent the formation of pinholes in GUARDKOTE 140 overlays when the binder, the aggregate, and the surface are heated to 100°F.

Final testing, to more clearly detect the presence of pinholing in GUARDKOTE overlays, was carried out on concrete and steel surfaces using acid solutions. The GUARDKOTE was applied to the concrete and steel surfaces, allowed to cure for 24 hours, and then saturated with acid solutions. The appearance of bubbling indicated a reaction between the concrete and/or the steel substrate and the presence of pinholes. The results of these tests appear in Tables VIII and IX. The 36 GUARDKOTE 140 systems tested appear in

Table VIII. The 28 GUARDKOTE 120 systems evaluated appear in Table IX. In testing most of the compositions, a total of 25 trials was run. Only six trials of a few systems were run when it immediately became obvious that the overlays contained pinholes. In order to pass the test, a system had to be perfect. All 25 trials had to show bubble-free results or they were eliminated and judged unsatisfactory.

Of the 36 GUARDKOTE 140 systems tested, 10 showed no evidence of containing pinholes. Four of the ten (systems 7, 8, 9, and 10) were standard GUARDKOTE 140, applied at 3 pounds per square yard on unetched portland cement concrete (PCC). They were surfaced with 6-12, 8-30, 12-30, and 14-24 emery aggregate supplied by American Abrasive Company, Westfield, Massachusetts. Three other pinhole-free GUARDKOTE 140 systems (12, 13, and 14) applied on unetched PCC at 2.5 pounds per square yard contained 1% Cab-O-Sil. They were surfaced with 8-30, 12-30, and 14-24 emery aggregate. Over acid-etched PCC two GUARDKOTE systems applied at 2.5 pounds per square yard and surfaced with 12-30 and 14-24 emery aggregate showed no pinholes (see systems 17 and 18). Finally, GUARDKOTE 140 (system 35) containing 2% Cab-O-Sil, applied at 2.5 pounds per square yard on steel, and surfaced with 12-30 emery also showed no pinholes.

Thirteen of 28 GUARDKOTE 120 systems showed no evidence of pinholing. System 7, GUARDKOTE 120 at 3 pounds per square yard applied on steel and surfaced with 16-40 quartz sand was pinhole free. On unetched PCC, systems applied at 2.5 and 3 pounds per square yard and surfaced with 30-100 and 16-40 quartz sand (3 pound application only) showed no pinholes. See systems 11, 14, and 15. On steel, GUARDKOTE 120 containing 2 and 3% Cab-O-Sil, applied at 2.5 pounds per square yard and surfaced with 16-40 quartz sand, gave overlays exhibiting no pinholing. The same was true of a system surfaced with 10-30 quartz sand, applied at 2.5 pounds per square yard on steel that contained 3% Cab-O-Sil. See systems 19, 21, and 22.

Systems 23 through 28, GUARDKOTE 120 applied at 2.5 pounds per square yard on steel, also showed no evidence of pinholing. Two types of aggregate (16-40 and 10-30 quartz sand) and three levels of Cab-O-Sil concentration (1, 2, and 3%) were used in these six systems.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study have shown that pinholing may be eliminated in the laboratory in six different ways. Only one of the six methods (decreasing aggregate particle size), however, appears feasible. The complete list of these techniques is as follows.

1. Use of finer aggregate
2. Application of a second binder layer
3. Application of no excess aggregate
4. Addition of Cab-O-Sil to the binder (increase the viscosity)
5. Use of thicker layers of binder
6. Delay the application of aggregate

The use of finer aggregate appears to be the best method of eliminating pinholing. As seen in the work reported in Tables IV and V, pinholing decreases as the aggregate particle size decreases. To avoid jeopardizing adhesion by bond-line starvation, however, aggregate mixes containing more than 5% of the particles passing a 40 mesh screen should not be used.

Application of a second binder layer is a sure way of sealing pinholes. This method was used on the Ohio Street Bridge job in Chicago and was very successful. The method does, however, raise the cost of a GUARDKOTE job through added materials and labor.

The application of only the required amount of aggregate is a promising approach. The advantages are that no aggregate will be wasted through excess quantities, and no labor would be required to sweep up excess grit after the overlay has cured. This is not feasible, however, because suitable equipment at a reasonable cost is not available.

The addition of Cab-O-Sil to the GUARDKOTE binder which will increase the viscosity is another possibility. Difficulties could arise, however, as a result of using different techniques for incorporating the Cab-O-Sil in the binder. With different GUARDKOTE licensees making the material, different mixing and blending methods are likely to be used. This could possibly result in binders having viscosities too high for the automatic paving equipment to handle.

Using higher binder rates (thicker overlays) would probably add too much to material cost, and therefore this method is not considered a promising one.

Finally, delaying the application of grit would be a technically feasible method of eliminating pinholing. As cure advances, the viscosity increases to the point where the addition of excess aggregate will not cause pinholing. However, since rate of cure depends on many variables and is difficult to control, this seems like a dangerous approach. In judging the length of time available for grit application, one must consider the surface temperature, the GUARDKOTE temperature, and the amount of sunlight. In addition, the possibility of breakdowns of spreading equipment and traffic jams have to be considered. Taking these factors into consideration, it seems somewhat risky to rely solely on a contractor's inexperienced superintendent or foreman to judge how long a delay in grit application would be desirable.

It is, therefore, recommended that GUARDKOTE Cements be applied at a minimum of 2.5 pounds per square yard and surfaced with 12-30 mesh aggregate.

PARTICIPANTS IN WORK REPORTED

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TECHNICAL REFERENCES

Technical Records Book, Volume 1219, pages 5-49

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APPENDIX

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TABLE IV

The Effect of Aggregate Particle Size on Pinholing in GUARDKOTE 140 Overlays

Per Cent By Weight Retained on Sieves

Systems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
US Standard Sieve Number																				
6	1			14																
8		13		55	55	7					1									
10	77																			
12	22	58	6			45													6	
14			18							2									18	
16		29	25	18	22	28				21	28		100						25	
18			18							23				100					18	
20			15							23					100				15	
25			9						100	15						100			9	
30			7	10	15	20	12			13	34						100		7	
35			2				25			3								100	2	
40							30													
45							13					1								
50				3	8		6				21	5								
60							5	100				20								
70							4					22								
80							3					18								100
100							2					17								
120												17								
200											16									
Grit Type	E	E	E	E	E	E	E	A	A	E	E	E	E	E	E	E	E	E	E	A
Binder Rate, lb/sq yd	3	3	3	3	3	3	3	3	3	3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Pinholes	yes	yes	yes	yes	yes	yes	no	no	no	yes	yes	no	yes	yes	yes	yes	yes	no	yes	no

Key to Grit Type (applies throughout this table)

E - Emery　　S - Silica
A - Alumina　　BB - Black Beauty

TABLE IV Continued

Systems	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
US Standard Sive Number	Per Cent by Weight Retained on Sieves																			
6		1																		
8									25	25										
10	47	54					1	1												
12							8	8	34	34										
14							22	22	12	12										
16	47	44			2	2	27	27	10	1[illegible]	42	42	36	37						
18					20	20	21	21	8	[illegible]	13	13			22	21	24			
20	5	1			31	31	7	7	7	7	11	11	22	21	18	17	16			
25	1										8	8	7	7	13	12	12	22	20	19
30			2	2	40	40	12	12	4	4	6	6	6	6	10	10	9	18	17	15
35											7	7	8	7	12	12	10	21	18	17
40			21	21	7	7	2	2												
45											8	8	11	9	18	15	12	29	24	22
50			38	38							3	3	4	3	7	6	5	10	9	8
60													6	5		7	6		12	10
70			28	28																
80														5			6			9
100			11	11																
Grit Type	E	E	S	S	S	S	S	S	S	S	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2,3	2,3	2	3	2	3	2	3	2	3	2	3	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	no	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	no	no

TABLE IV Continued

Systems	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
US Standard Sieve Number	Per Cent by Weight Retained on Sieves																			
8												4	4							
10												6	6							
16	19	49										35	35	42	42	24	24			
20	24	18	28	33	33							20	20	23	23	21	21			
25											100									
30	21	12	26	21	21	40	41	35	11			12	12	13	13	15	15	82	82	69
35	9	5	11	10	11	16	15	15												
40																		18	18	12
45	13	6	17	18	16	24	22	21				10	10	11	11	16	16			
50	14	5	18	18	15	20	22	20	78											
60		1			1				6	100		7	7	7	7	12	12			12
80		4			3			9	4			3	3	3	3	8	8			5
100									1			1	1	1	1	4	4			2
120												2	2							
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	3	3	3	3	3	3	3	3	2	2	2	2	3	2	3	2	3	2	3	2
Pinholes	yes	no	no	no	no	no	no	no	yes	no	yes	yes	no	yes	no	no	no	no	no	no

TABLE IV Continued

Per Cent by Weight Retained on Sieves

Systems	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
US Standard Sieve Number																				
8		10	10	10	10	10	10	10	10	10	10									
12		10	10	15	15	15	20	20	20	25	25	10	10	10	5	5	5	5	5	5
20		30	50	20	35	45	25	30	40	20	30	40	30	25	45	40	35	30	45	35
30	69	40	20	45	30	20	35	30	20	35	25	40	50	55	40	45	50	55	45	55
40	12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	5	5
60	12																			
80	5																			
100	2																			
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

											Per Cent by Weight Retained on Sieves									
Systems	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
US Standard Sieve Number																				
10	5																			
12		10	10	10	10	10	10	10	10	10	10	5	5	5	5	5	5	5	5	5
20	30	10	10	15	15	20	10	10	10	5	5	15	10	10	15	10	15	20	15	15
30	60	35	25	30	20	25	25	30	35	20	30	50	45	40	35	35	25	50	45	35
40	5	35	45	35	45	35	50	45	40	60	50	20	30	35	35	40	45	20	30	40
50		10	10	10	10	10	5	5	5	5	5	10	10	10	10	10	10	5	5	5
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Per Cent by Weight Retained on Sieves

Systems	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
US Standard Sieve Number																				
12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
20	10	15	10	10	10	10	10	10	10	10	10	10	10	10	10	10	15	15	15	15
30	25	60	60	55	30	25	35	25	20	40	50	30	20	40	50	35	30	25	20	35
40	55	10	15	20	45	50	35	45	50	30	20	35	45	25	15	30	30	35	40	25
50	5	10	10	10	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20	20
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
	Per Cent by Weight Retained on Sieves																			
US Standard Sieve Number																				
12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5				
16																	5	5	5	5
20	15	10	10	10	10	10	10	10	10	10	10	10	15	15	15	15	15	20	30	40
30	40	15	15	15	15	20	20	20	25	25	25	25	15	20	20	25	30	35	35	35
40	20	35	40	45	50	30	35	40	25	30	35	40	40	35	45	30	50	40	30	20
50	20	35	30	25	20	35	30	25	35	30	25	20	25	25	15	25				
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
	Per Cent by Weight Retained on Sieves																			
US Standard Sieve Number																				
16	5	5	15	15	15	15	20	20	20	25	35									
20	50	45	20	25	40	35	20	35	30	25	30	10	10	10	10	10	10	20	20	20
30	30	45	25	30	25	35	25	25	30	25	20	20	25	30	35	40	40	20	35	30
40	15	5	40	30	20	15	35	20	20	25	15	30	30	30	30	30	40	25	25	30
50												40	35	30	25	20	10	35	20	20
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
	Per Cent by Weight Retained on Sieves																			
US Standard Sieve Number																				
20	25	25	25	30	35	40	5	5	5	5	5	10	10	10	10	10	5	5	5	5
30	30	35	25	25	30	30	10	10	15	15	15	10	10	10	15	15	10	5	5	5
40	35	25	25	25	20	20	25	35	25	30	35	25	30	40	20	25	20	45	35	25
50	10	15	25	20	15	10	60	50	60	50	45	55	50	40	55	50	65	45	55	65
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes

TABLE IV Continued

Systems	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
	Per Cent by Weight Retained on Sieves																			
US Standard Sieve Number																				
20	5														5	5	5	5	10	10
25		5	5	5	5	5	10	10	10	10	10	10	10	10						
30	5	5	5	10	10	10	10	10	10	15	15	15	20	20	15	30	45	55	15	30
40	55	45	35	40	30	25	40	30	20	35	25	20	30	20	80	65	50	40	75	60
50	35	45	55	45	55	60	40	50	60	40	50	55	40	50						
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Per Cent by Weight Retained on Sieves

Systems	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
US Standard Sieve Number																				
20	10	10	15	15	15	15														
25							5	5	5	5	10	10	10	10	15	15	15	15		
30	45	60	20	30	40	55	15	30	45	65	15	30	45	60	20	30	40	55	5	5
40	45	30	65	55	45	30	80	65	50	30	75	60	45	30	65	55	45	30	15	45
50																			80	50
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
US Standard Sieve Number	Per Cent by Weight Retained on Sieves																			
25							22	20	19	20	20	20	20	25	25	25	25	30	30	30
30	5	10	10	15	15	15	18	17	15	20	20	20	30	15	20	25	25	20	25	30
40	65	30	45	30	40	55	50	42	39	30	40	50	20	45	45	25	40	30	25	20
50	30	60	45	55	45	30	10	9	8	30	20	10	30	15	10	25	10	20	20	20
60								12	10											
80									9											
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
US Standard Sieve Number	Per Cent by Weight Retained on Sieves																			
25	10	15	15	15	20	20	20	25	25	25	30	22	20	19	20	20	20	20	25	25
30	20	10	15	20	15	20	20	15	20	25	25	18	17	15	20	20	20	30	25	25
40	40	45	40	20	45	20	40	40	20	20	20	50	42	39	30	40	50	20	25	40
50	20	10	15	20	10	20	10	5	20	15	15	10	9	8	30	20	10	30	25	10
60	10	20	15	25	10	20	10	15	15	15	10		12	10						
80														9						
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2	2	2	2	2	2	2	2	2	2	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

Systems	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
	Per Cent by Weight Retained on Sieves																			
US Standard Sieve Number																				
25	25	25	30	30	30	10	15	15	15	20	20	20	25	25	25	30	10	13	16	20
30	25	25	20	25	30	20	10	15	20	15	20	20	15	20	25	25	12	14	17	19
35																	15	16	17	18
40	25	40	30	25	20	40	45	40	20	45	20	40	40	20	20	20	18	18	17	16
45																	21	19	17	14
50	25	10	20	20	20	20	10	15	20	10	20	10	5	20	15	15	24	20	16	13
60						10	20	15	25	10	20	10	15	15	15	10				
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pinholes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IV Continued

	Per Cent by Weight Retained on Sieves									
Systems	281	282	283	284	285	286	287	288	289	290
US Standard Sieve Number										
10							100			33
16								100		34
25	24	10	13	16	20	24			100	33
30	21	12	14	17	19	21				
35	18	15	16	17	18	18				
40	15	18	18	17	16	15				
45	12	21	19	17	14	12				
50	10	24	20	16	13	10				
Grit Type	E	E	E	E	E	E	BB	BB	BB	BB
Binder Rate, lb/sq yd	2.5	2.5	2.5	2.5	2.5	2.5	2	2	2	2
Pinholes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes

TABLE V

Aggregate Mixtures Producing Pinhole-Free GUARDKOTE 140 Overlays on Glass (Visually Observed)

System	Aggregate	Binder Rate, lb/sq yd	US Standard Sieve Number 8	10	12	14	16	18	20	25	30	35	40	45	50	60	70	80	100	120
12	Emery	2												1	5	20	22	18	17	17
18	Emery	2										100								
20	Alumina	2																100		
38	Emery	2								22	18	21		29	10					
39	Emery	2								20	17	18		24	9	12				
40	Emery	2								19	15	17		22	8	10		9		
50	Emery	2														100				
56	Emery	2					24		21		15			16		12		8	4	
58	Emery	2									82		18							
60	Emery	2									69		12			12		5	2	
177	Emery	2							5		10		20		65					
221	Emery	2									5		65		30					
284	Emery	2.5								16	17	17	17	17	16					
12	Emery	3												1	5	20	22	18	17	17
18	Emery	3										100								
20	Alumina	3																100		
24	Silica	3									2		21		38		28		11	
30	Silica	3	25		34	12	10	8	7		4									
42	Emery	3					49		18		12	5		6	5	1		4		
43	Emery	3							28		26	11		17	18					
44	Emery	3							33		21	10		18	18					
45	Emery	3							33		21	11		16	15	1		3		
46	Emery	3									40	16		24	20					
47	Emery	3									41	15		22	22					
48	Emery	3									35	15		21	20			9		
53	Emery	3	4	6			35		20		12			10		7		3	1	2
55	Emery	3					42		23		13			11		7		3	1	
57	Emery	3					24		21		15			16		12		5	2	
59	Emery	3									82		18							
61	Emery	3									69		12			12		5	2	

TABLE VI

The Effect of Aggregate Particle Size and the Addition of Cab-O-Sil on Pinholing in GUARDKOTE 140 Overlays

Per Cent by Weight Retained on Sieves

Systems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
US Standard Sieve Number																				
12		6			5	5	5	5	10	5	5	5	5	5	5	5	5	5	5	
14	2	18																		
16	21	25			8	10	10	15	15	10	7	5	10	5	10	7	5	10	10	5
18	23	18	100																	
20	23	15		100	11	10	15	15	15	20	9	10	10	15	15	8	10	10	10	7
25	15	9			14	15	15	15	15	30	11	10	10	15	20	10	10	10	15	9
30	13	7			17	15	15	15	15	20	13	15	15	15	20	11	10	10	20	11
35	3	2			20	20	15	15	15	10	15	15	15	15	15	13	10	10	15	13
40					25	25	25	20	15	5	17	20	15	15	10	14	15	15	10	15
45																				17
50											23	20	20	15	5	16	15	15	10	23
60																16	20	15	5	
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Cab-O-Sil, % by wt	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no

Key to Grit Type: E = Emery

TABLE VI Continued

Systems	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
									Per Cent by Weight Retained on Sieves								
US Standard Sieve Number																	
16	5	5	5	5	5	5	5	5	5	5	5	5	28	5	5	5	10
20	5	10	5	10	7	5	10	10	10	10	15	15	23	8	10	10	5
25	10	10	15	15	8	10	10	10	15	15	15	20	19	11	10	15	15
30	10	10	15	20	10	10	10	15	19	20	20	20	15	14	15	15	15
35	15	15	15	20	11	10	10	20	23	20	20	20	10	17	15	15	15
40	15	15	15	15	13	10	10	15	28	30	25	20	5	21	20	20	15
45	20	15	15	10	14	15	15	10						24	25	20	15
50	20	20	15	5	16	15	15	10									
60					16	20	15	5									
Grit Type	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Binder Rate, lb/sq yd	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Cab-O-Sil, % by wt	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pinholes	no	no	yes	yes	no	no	no	yes	no	no	no	yes	yes	no	no	no	no

Key to Grit Type: E = Emery

TABLE VII

The Effect of Flow Modifiers on Pinholing[1)]

Flow Modifier Added to GUARDKOTE 140	Per Cent by Weight Added	Pinholes
None - Control	-	yes
Thixcin E	1, 2, 3, 4, 5, and 6	yes
AGE/AYAF - 95/5	2, 4, and 6	yes
AGE/AYAF - 90/10	4 and 6	yes
AGE/AYAF - 85/15	2, 4, and 6	yes
AGE/AYAF - 75/25	2, 4, and 6	yes
Ethyl Alcohol	1 and 3	yes
Furfuryl Alcohol	1 and 3	yes
Triethylamine	0.2, 0.5, 1, and 3	yes
EPON Curing Agent V-40	0.2, 0.5, 1, and 3	yes
N-Hexane	0.2, 0.5, 1, and 3	yes
SF-69	0.2 and 1	yes
Antifoam A	0.2 and 1	yes
Triethylene Glycol	0.2 and 1	yes
Tween 20	0.2 and 1	yes
SR-82	0.2 and 1	yes
Span 80	0.2 and 1	yes
Aerosol C-61	0.2 and 1	yes
Anti-Sag 7	0.2 and 1	yes
Duomeen S	0.3 and 1	yes
Duomeen O	0.3 and 1	yes
Duomeen C Residue	0.3 and 1	yes
Duomeen C and S Residue	0.3 and 1	yes

1) The GUARDKOTE 140 binder, the aggregate, and the glass surface were heated to 100°F before application

TABLE VIII

The Detection of Pinholing in GUARDKOTE 140 Overlays Using Acid Solutions

System	Binder Rate, lb/sq yd	Emery Aggregate, mesh	Surface[1)]	Cab-O-Sil, %w	Pinhole-Free Trials[2)]
1	1	6-12	Unetched PCC	-	3 of 6
2	1	14-24	Unetched PCC	-	2 of 6
3	2.5	6-12	Unetched PCC	-	1 of 6
4	2.5	8-30	Unetched PCC	-	5 of 6
5	2.5	12-30	Unetched PCC	-	4 of 6
6	2.5	14-24	Unetched PCC	-	4 of 6
7	3	6-12	Unetched PCC	-	25 of 25
8	3	8-30	Unetched PCC	-	25 of 25
9	3	12-30	Unetched PCC	-	25 of 25
10	3	14-24	Unetched PCC	-	25 of 25
11	2.5	6-12	Unetched PCC	1	18 of 25
12	2.5	8-30	Unetched PCC	1	25 of 25
13	2.5	12-30	Unetched PCC	1	25 of 25
14	2.5	14-24	Unetched PCC	1	25 of 25
15	2.5	6-12	Etched PCC	-	23 of 25
16	2.5	8-30	Etched PCC	-	21 of 25
17	2.5	12-30	Etched PCC	-	25 of 25
18	2.5	14-24	Etched PCC	-	25 of 25
19	1	6-12	Steel	-	15 of 25
20	1	14-24	Steel	-	0 of 25
21	2.5	6-12	Steel	-	15 of 25
22	2.5	8-30	Steel	-	10 of 25
23	2.5	12-30	Steel	-	20 of 25
24	2.5	14-24	Steel	-	0 of 25
25	3	6-12	Steel	-	20 of 25
26	3	8-30	Steel	-	20 of 25
27	3	12-30	Steel	-	12 of 25
28	3	14-24	Steel	-	12 of 25
29	2.5	6-12	Steel	1	0 of 25
30	2.5	8-30	Steel	1	8 of 25
31	2.5	12-30	Steel	1	0 of 25
32	2.5	14-24	Steel	1	5 of 25
33	2.5	6-12	Steel	2	8 of 25
34	2.5	8-30	Steel	2	0 of 25
35	2.5	12-30	Steel	2	25 of 25
36	2.5	14-24	Steel	2	8 of 25

1) Portland cement concrete (PCC) surfaces that were etched were treated with 16% solutions of hydrochloric acid

2) The results show the number of pinhole-free overlays obtained out of the indicated number of test trials

TABLE IX

The Detection of Pinholing in GUARDKOTE 120 Overlays Using Acid Solutions

System	Binder Rate, lb/sq yd	Quartz Aggregate, mesh	Surface[1)]	Cab-O-Sil, %w	Pinhole-Free Trials[2)]
1	1	30-100	Steel	-	0 of 25
2	1	10-30	Steel	-	8 of 25
3	2.5	30-100	Steel	-	0 of 25
4	2.5	16-40	Steel	-	5 of 25
5	2.5	10-30	Steel	-	8 of 25
6	3	30-100	Steel	-	0 of 25
7	3	16-40	Steel	-	25 of 25
8	3	10-30	Steel	-	8 of 25
9	1	30-100	Unetched PCC	-	0 of 25
10	1	10-30	Unetched PCC	-	0 of 25
11	2.5	30-100	Unetched PCC	-	25 of 25
12	2.5	16-40	Unetched PCC	-	20 of 25
13	2.5	10-30	Unetched PCC	-	20 of 25
14	3	30-100	Unetched PCC	-	25 of 25
15	3	16-40	Unetched PCC	-	25 of 25
16	3	10-30	Unetched PCC	-	15 of 25
17	2.5	16-40	Steel	1	17 of 25
18	2.5	10-30	Steel	1	17 of 25
19	2.5	16-40	Steel	2	25 of 25
20	2.5	10-30	Steel	2	20 of 25
21	2.5	16-40	Steel	3	25 of 25
22	2.5	10-30	Steel	3	25 of 25
23	2.5	16-40	Unetched PCC	1	25 of 25
24	2.5	10-30	Unetched PCC	1	25 of 25
25	2.5	16-40	Unetched PCC	2	25 of 25
26	2.5	10-30	Unetched PCC	2	25 of 25
27	2.5	16-40	Unetched PCC	3	25 of 25
28	2.5	10-30	Unetched PCC	3	25 of 25

1) PCC = Portland cement concrete
2) The results show the number of pinhole-free overlays obtained out of the indicated number of trials

GLOSSARY

Advawet 10	Wetting agent, Advance Solvents and Chemical Company
Advawet 82	Wetting agent, Advance Solvents and Chemical Company
Aerosol C-61	Surface active agent, American Cyanamid Co.
AGE	Allyl glycidyl ether
Alumina	Synthetic aluminum oxide
Antifoam A	Defoaming agent, Dow Corning Corporation
Asbestos 7TF1	Johns-Manville Corporation
AYAF	Vinyl resin, Union Carbide Corporation
Beetle 216-8	Urea-formaldehyde resin, American Cyanamid Co.
Bentone 27	Gelling agent, National Lead Company
Black Beauty Aggregate	Boiler slag aggregate, H. B. Reed and Company
Cab-O-Sil	Colloidal silica thixotropic agent, Godfrey L. Cabot, Inc.
Celite 1655	Diatomaceous silica filler, Johns-Manville Corp.
DC-200	Silicone oil, Dow Corning Corporation
Duomeen C Residue	Alkyldiamine bottoms, Armour Chemical Division
Duomeen C and S Residue	Mixture of alkyldiamine bottoms, Armour Chemical Division
Duomeen O	Alkyldiamine, Armour Chemical Division
Duomeen S	Alkyldiamine, Armour Chemical Division
Emery	Naturally occurring crude aluminum oxide
MCG-1	Mineral filler, Nopco Chemical Corporation
Microcel E	Calcium silicate extender, Johns-Manville Corp.

GLOSSARY Continued

Nuosperse 657	Surface active agent, Nuodex Products Co.
Pluronic L-61	Surface active agent, Wyandotte Chemicals Corp.
Sag 47	Defoaming agent, Union Carbide Corporation
SF-69	Silicone resin, General Electric Company
Slate Flour	Mineral filler, Whittaker, Clark and Daniels, Inc.
Span 80	Wetting agent, Atlas Powder Company
SR-82	Silicone resin, General Electric Company
Suspenso	Calcium carbonate filler, Diamond Alkali Co.
Thixcin E	Thixotropic agent, Baker Castor Oil Company
Tween 20	Wetting agent, Atlas Powder Company
Wollastonite P-1	Solid mineral filler, Godfrey L. Cabot, Inc.