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16. Abstract

The objective of this research was to determine the causes of and to find remedies for the darkening and/or peeling problems experienced with some types of concrete coatings. Other states were surveyed and field inspections of several locations in Texas districts were performed in order to identify possible variables which may cause darkening or peeling of coatings. The variables identified included type and thickness of coatings, level of concrete and coating textures, and condition of concrete surfaces. A test panel program was then conducted in which the effect of each variable or a combination of variables was investigated. Recommendations are made which should reduce or eliminate many of the problems.

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INVESTIGATION OF CONCRETE COATING PROBLEMS

by

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Research Report 451-1F

Research Project 3-9-86-451
Concrete Coating Problems

conducted for

Texas State Department of Highways
and Public Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

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Bureau of Engineering Research
The University of Texas at Austin

November 1987

PREFACE

Many people have contributed to this investigation. Joe Raska of the Materials and Tests Division served as Technical Advisor and offered many insights and suggestions based on his many years of experience, and most of his observations were confirmed during the course of the investigation. Arthur Barrow, also of the Materials and Tests Division, was also a vital part of the research in assisting in the field surveys, obtaining the colorimeter readings, and performing the chemical analysis on the coating samples collected during the field survey.

Tex Hood of H and H Materials was very helpful in providing observations of possible causes and solutions from the contractor's point of view. He performed the spraying of the coatings for the test panels without cost. His help is greatly appreciated.

Many of our graduate students and staff were involved. David Price, former graduate student, performed many of the field surveys, organized the test panel program and assisted in the writing of the report. Mohamed Abdul-Malak, a current graduate student, completed the panel tests including the analysis and wrote most of the report. David P. Whitney and Don Dombroski, of the technical staff played an important role in the test panel program. Joy Suvunphugdee typed the final report. Rose Rung was the administrative assistant.

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ABSTRACT

The objective of this research was to determine the causes of and to find remedies for objective darkening and/or peeling problems experienced with some types of concrete coatings. Other states were surveyed and field inspections of several locations in Texas districts were performed in order to identify possible variables which may cause irregualr darkening or peeling of coatings. The variables identified included type and thickness of coatings, level of concrete and coating textures, and condition of concrete surfaces. A test panel program was then conducted in which the effect of each variable or a combination of variables was investigated. Recommendations are made which should reduce or eliminate many of the problems.

SUMMARY

The overall scope of the study was to investigate the possible causes of the irregular non-uniform darkening and peeling problems experienced in Texas with some types of coatings. For that purpose, a survey of other states and field surveys of several Texas districts were performed. The variables identified included type and thickness of coatings, concrete and coating textures, and condition of concrete surfaces before coatings were applied. A test panel program was conducted in which the significance of each identified variable or a combination of variables was investigated.

IMPLEMENTATION STATEMENT

The results of this study can be implemented throughout the state. Recommendations are made for the elimination of coatings when feasible. Where coatings are used, suggestions are given which should reduce objectionable darkening and peeling. The implementation of these suggestions will result in reduced maintenance costs and more attractive highway structures.

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CHAPTER 1. INTRODUCTION

1.1 PROBLEM

Several districts in the state have reported problems with concrete coatings used on construction projects. In some cases the coatings became unsightly with irregular dark and light areas; in other cases the coatings peeled or flaked. Some surfaces have maintained a good appearance for years; others have turned dark or peeled after a short time.

1.2 BACKGROUND AND SIGNIFICANCE OF WORK

All concrete coatings used on construction projects by the Texas State Department of Highways and Public Transportation (SDHPT) must satisfy specification D-9-8110 Structural Coatings. The specification includes requirements on (1) shelf stability, (2) paint non-volatile content, (3) pigment content, (4) viscosity, (5) appearance of applied coating, (6) hiding power, (7) flexibility, (8) mildew resistance, (9) moisture resistance, (10) accelerated weathering, (11) weight per gallon, (12) infrared spectrum, and (13) vehicle composition.

The specification further states that

> the Class B structural coating shall be a paint-type material, consisting of a synthetic resin containing fibrous as well as texturing pigments. When applied by one-coat spray application at a rate of 45 plus or minus 5 square feet per gallon, the finish shall be uniform in texture and appearance, and free of runs and sags on vertical surfaces.

All of the currently approved coatings are alkyd-based except one which is acrylic-based.

Prior to the beginning of this study, the Fort Worth District (2), the Waco District (9), and the San Antonio District (15) indicated coating problems for which they had not been able to identify the cause. Problems were encountered in particular on bridges and medians, both in surfaces exposed to the sun and in surfaces that are always shaded.

Personnel from the districts and the Materials and Tests Division (D-9) of the SDHPT suggested several possible causes for the coatings turning dark and/or peeling or flaking:

(1) coarse texture of the coatings, which collects dust and dirt, turning the surface dark,

(2) uneven coating film thickness (the application rate is different than the specified 45 ± 5 sq ft/gal),

(3) coatings which do not meet specifications (even though the types and manufacturers have been initially approved for prequalified material on bid lists),

(4) inadequate preparation of the surface, e. g., asphalt on a surface should be adequately cleaned by sandblasting and/or waterblasting,

(5) spray-on curing compound which is not removed,

(6) coatings on slipformed median barrier surfaces—these often peel while precast units seldom peel, and

(7) the presence of iron oxide; in one case, it was found that this caused the coating to darken.

A painting contractor who works extensively for the State Department of Highways and Public Transportation (SDHPT) was interviewed to determine what he thought causes the problems. He expressed several opinions.

(1) He is aware of only one brand of coating which itself changed color. That particular brand is no longer sold.

(2) In shaded areas mildew causes the surface to turn dark.

(3) Slow drying coatings attract contaminants which adhere and cannot be washed off by rain.

(4) Traffic emissions cause some surfaces to turn dark.

(5) Texture in the paint causes uneven thicknesses when an overlap occurs; the impinging of the Perlite® granules (added to provide texture to the coating) on the overlapped coating surface causes small craters which collect contaminants.

(6) Excessively thick curing compound tends to chalk, which can cause peeling.

(7) Slipformed median barriers have experienced peeling apparently because of a white, chalky substance that develops on the surface. It does not occur on cast-in-place median barriers.

(8) Most exposed concrete surfaces have a mottled appearance after construction and need to be coated.

(9) Surfaces to be coated should generally be waterblasted prior to the coating application.

(10) Other coatings, such as latex, should be considered.

(11) Faster drying coatings, such as SDHPT No. 742, used for steel surfaces, should be used to minimize insurance claims due to spray falling on passing vehicles.

1.3 SCOPE OF STUDY

The investigation included a summary of a survey of problems of other states performed by the Transportation Planning Division (D-10) of SDHPT; a survey of Districts within the state; and a test-panel program. The report includes the following sections:

Chapter 2 summarizes the results of the survey of other states. Chapter 3 describes the field survey in which structures with coating problems were examined. Chapter 4 summarizes the test panel program to investigate the effect of many variables on coating performance. Chapter 5 gives an analysis of the test-panel program results. Chapter 6 gives conclusions and recommendations.

CHAPTER 2. SURVEY OF OTHER STATES

2.1 SCOPE OF SURVEY

The Transportation Planning Division (D-10) of the SDHPT conducted a survey to determine if problems with concrete coatings had been encountered in other states. The survey sought information on the nature of coating problems experienced, the causes if known, and the remedies if attempted. Responses were received from thirty-six states, twenty-four of which reported no serious problems with concrete coatings. The other twelve states reported that they had had problems with concrete coatings and gave descriptions of the encountered problems and the solutions attempted. Coatings which had exhibited satisfactory performance were also recommended by some of the surveyed states.

2.2 PROBLEMS REPORTED BY OTHER STATES

All of the twelve states which reported problems with concrete coatings indicated that darkening and staining of coatings had been experienced. Only one state, West Virginia, reported problems with both darkening and peeling of concrete coatings. Numerous factors were reported which may have possibly caused concrete coatings to darken. These were

(1) dust and vehicle exhaust emissions (Arkansas, South Carolina, and West Virginia),
(2) mildew and water (Mississippi),
(3) coarse texture of coatings (Tennessee), and
(4) the use of certain types of coatings such as Stan-Lux® (Arkansas and Georgia), Tec-Kote® (Mississippi), and Thoroseal® (Oklahoma).

States which had attempted to remedy the darkening problem and states which had no problems with darkening suggested solutions and provided information that may help prevent concrete coatings from darkening. These involved

(1) eliminating certain types of coatings (Arkansas and Georgia no longer use Stan-Lux®),
(2) the use of silicone/silane sealers for moisture control (California),
(3) the use of acrylic paint sealers (Colorado and Oregon),
(4) the application of Thoroseal® (Minnesota, New Mexico, and North Dakota) — this contradicts the rapid discoloration problems experienced in Oklahoma with Thoroseal®,
(5) the use of epoxy coating (Vermont), and
(6) the use of latex emulsion paint (Wyoming).

Table 2.1 summarizes the responses received from each of the responding states.

TABLE 2.1 SUMMARY OF THE RESPONSES RECEIVED FROM OTHER STATES

State	Problem	Solution	Other Information
Alaska		No problem	
Arizona		No problem	
Arkansas	Discoloration on 2 structures in a "high traffic" area. Both used Stan-Lux®, manufactured by Standard T Chemical of Dallas.	Stan-Lux® no longer used.	In-house testing inconclusive
California	Minor problems with (a) concrete stains from plywood formwork and (b) concrete stains from steel formwork.	Removal of stains already in place has not been attempted.	Both epoxy and urethane finishes turn brown or yellow with time. Silicone/silane sealers and high molecular weight methacrylate do not discolor at all.
Colorado	One structure has discolored	Recommend acrylic paint sealer.	Specifications attached
Connecticut	No problem		
Florida	No problem		

(Continued)

TABLE 2.1 (CONTINUED)

State	Problem	Solution	Other Information
Georgia	Discoloration on structures using Stan-Lux®	Eliminate certain types of surface coatings	Specifications attached
Hawaii	No problem		
Idaho	Formula 13-82 (specification provided) performs successfully	Use other formulas for guardrails	Specifications attached. Flyash with loss on ignition greater than 1.5% may discolor concrete
Illinois	Some problems but they are considered to be normal	Have limited experience with use of clear vinyl to keep weathering steel from staining concrete	Specification attached
Indiana	No problem		
Iowa	No problem		Specification attached
Kentucky	Problems with masonry coatings (not concrete)		Masonry coating, specifications attached
Louisiana	No problem		No coatings applied
Maine	No problem		
Michigan	No problem		Approved list of de-icing chemicals furnished
Minnesota	No problem		Thorosheen® manufactured by Standard Dry Wall
Mississippi	Early discoloration on one structure possibly due to use of Texcoat®; later discoloration due to mildew and water stain	No solution	
Missouri	No serious problem	Have tried a K-M coating a shot-crete mixture with M-2 additive, as well as an unknown type of paint with no success; have used some white cement on median barriers for safety -worked well to retain color	Tennessee apparently has effective treatment which they have used on I-155 over the Mississippi River
Nebraska	No problem		
Nevada	No problem		
New Hamphire	No problem		

(Continued)

TABLE 2.1 (CONTINUED)

State	Problem	Solution	Other Information
New Mexico	Some discoloration occurring in Albuquerque area	Application of Thoroseal® has helped somewhat	Thoroseal® literature furnished
North Carolina	No problem		Surfaces sprayed with Thoroseal®, then sealed with Thorosheen®
Ohio	Structures darken with age, but no complaints have been received		Specifications attached
Oklahoma	Some immediate darkening problems with Thoroseal®	Approved list furnished	
Oregon	No problem		Materials commonly used: clear solution-borne acrylics; gray, water-based, 100% acrylic
South Carolina	Problem but no solutions-assume darkening is due to surface remaining tacky so dust adheres		
South Dakota	No problem	Use commercial textured finish products	Information attached
Tennessee	Discoloration of textured coated surfaces in both urban and rural areas	None attempted	
Vermont	No problem	All concrete dark due to the use of linseed oil as a sealer	Suggests that epoxy coating might work
Washington	No problem		
West Virginia	Minor problems with concrete coatings fading, peeling and staining from diesel exhaust fumes. Uncoated concrete surfaces also stained from exhaust fumes.	Surfaces were recoated or cleaned	Pigmented curing compound also fade. Epoxy breaks down with UV light.
Wyoming	No problem		Latex emulsion paint used successfully; specifications attached.

2.3 COATINGS RECOMMENDED BY OTHER STATES

Some states attached copies of their specifications in which concrete coatings which had exhibited satisfactory performance were recommended. Among the various types of coatings recommended, acrylic coatings and Thoroseal® seem to have been used successfully in the majority of these states. Table 2.2 lists the concrete coatings recommended by each of these states.

TABLE 2.2 CONCRETE COATINGS RECOMMENDED BY OTHER STATES

State	Coatings Exhibiting Satisfactory Performance
California	silicone/silane sealer (moisture control), high molecular weight methacrylate (crack repair)
Georgia	acrylic polymer modified portland cement grout organic resin binder
Idaho	Vabar 300 (advertisement provided) Canyon Tone Stain (advertisement provided)
Iowa	Thoroseal® and Acryl 60 Akona Daraweld C and mortar Akkro 7T and Concrete Finisher Sikamix 131 (Sika Latex and Mortar) Intralok Bonding Agent and Mortar
Kentucky	TCA BridgeCote AM - Tex Thoroseal® and Acryl 60 TrikoPlex Onatex Seal Coat 1000 Prestonshield 1200
Michigan	Isoflex Hydrozo 30 or 600 PSI high Density Sinak #102 Chemtrete BSM 40 Sil-Act Stifel (the above products were chosen for protection against de-icing chemicals)
New Mexico	Thoroseal® and Acryl 60 (advertisement provided) Daraweld C and mortar
North Dakota	Thoroseal®, Thorosheen®
Ohio	Silane Epoxies (the above products were chosen for protection against de-icing chemicals)
Okalahoma	Akryl 60 Con-Cure Finish Hydrocide Super Colorcoat Kenitex Bridge Coating Prestonshield 1200 Secure Seacoat W Sonocrete Chemrex TCA Bridge-Coat Tamoseal and Akkro 7T Thoroseal®
Oregon	Acrylica

(Continued)

TABLE 2.2 (CONTINUED)

State	Coatings Exhibiting Satisfactory Performance
South Dakota	Thoroseal® and Akryl Akona Daraweld "C" Concrete Finisher and Akkro 7T
Vermont	50-50 solution of linseed oil and mineral spirits (expect uniform darkening to occur)
Wyoming	latex emulsion paint

CHAPTER 3. FIELD SURVEYS IN TEXAS AND ANALYSIS OF COATING SAMPLES

3.1 PURPOSE

Telephone surveys were conducted to determine which districts had experienced problems with concrete coatings. Districts which reported problems were visited, and field inspection and data collection surveys were made to determine the kinds of problems experienced. Information sought included

(1) description of problems encountered,
(2) locations of coating problems,
(3) types of coating applied,
(4) types of concrete structure coated (median, bridge, etc.),
(5) type of concrete; precast or cast-in-place,
(6) presence of curing compound,
(7) age of concrete when coating applied,
(8) date of coating application,
(9) weather conditions when coating was applied,
(10) type and volume of traffic, and
(11) personal observations of district personnel.

Field samples were collected and later analyzed by D-9 to determine possible causes of coating defects. Types of samples obtained included

(1) film samples of coatings which had shown irregular darkening and/or peeled,
(2) film samples of coatings from the same project which had experienced no problems, and
(3) samples of concrete beneath surface at selected locations.

In most cases, District personnel could not provide information on the type of coating, age of concrete at time coating was applied, use of curing compound, and weather conditions at time of coating.

3.2 FINDINGS OF FIELD SURVEYS

Eleven Districts in Texas were surveyed. Four Districts (Wichita Falls, Childress, Lubbock, and San Angelo) reported no problems with concrete coatings. The problems reported by the other seven Districts involved peeling and/or objectionable darkening of coatings, particularly on concrete bridges and median barriers. The findings of the field surveys and the results of the analysis performed on the obtained samples are summarized for each District as follows. The location within the district is shown in parentheses.

3.2.1 District 15 (San Antonio)

3.2.1.1 Findings of Field Surveys. Several miles of median barriers on the McAllister Freeway (US 281) and at the Fratt Interchange (IH 410 and IH 35) were inspected in San Antonio. The Fratt barrier coating had been applied in 1983. The coating was light tan in color and was said to be a product of Preston Pacific. The barrier displayed significant discoloration of the coating (Fig 3.1) on surfaces with rough texture. Throughout other locations in the district, severe peeling and discoloration of coatings were observed. Often, a "zebra-stripe" effect was evident on median barriers; that is, a repeating vertical pattern of darkened and lighter areas occurred at short irregular intervals, thus creating the appearance of zebra stripes. District personnel contacted felt that this could be due to the spray pattern in these areas and that the coating was either too thick or too thin in the darkened stripes.

In particular the McAllister Freeway median barrier exhibited significant peeling about one or two years after being painted with Prestonshield®. The barrier was cleaned with high pressure (9000 psi) water and repainted. However, it again began peeling (Fig 3.2).

Concerning the darkening problem in general, the personnel contacted believed that it could be due to vehicle

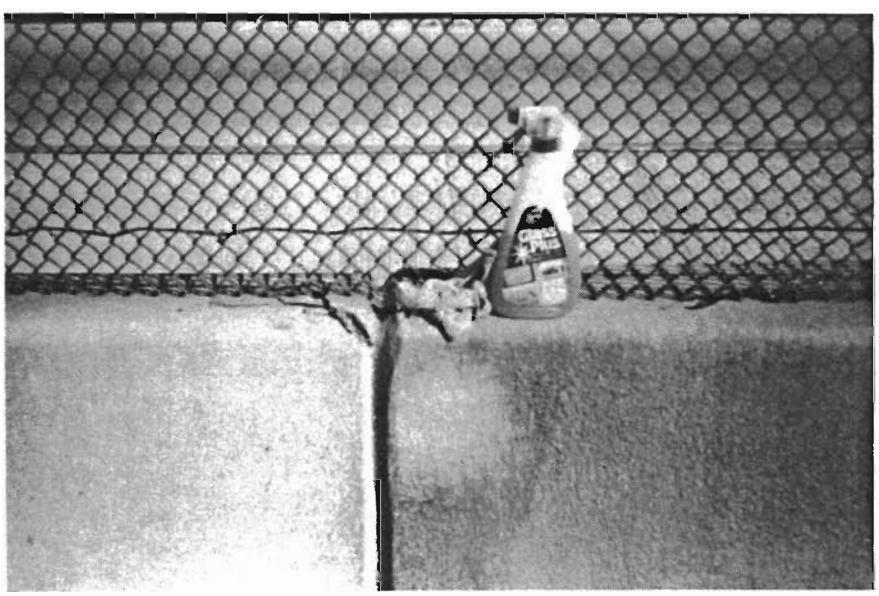


Fig 3.1. Discoloration on median barrier at the Fratt Interchange.

Fig 3.2. Peeling on median barrier on McAllister Freeway in San Antonio.

emissions and reported that darkening had been removed by the application of soap and water. They also reported that discoloration problems were observed in areas where coatings did not cure properly. Last, they related that all coatings in the District have been applied by the same contractor and that coatings applied from 1979 through 1984 are generally distressed whereas older and more recently applied coatings are not.

3.2.1.2 Results of Analysis of Samples Taken. Two coating samples were obtained from the side of the median barrier on the southbound of SH 281 south of IH 410. An analysis revealed identical results for both samples. From infrared analysis, the coating was found to be a typical alkyd resin. From X-ray diffraction, the compositions were found to be $CaCO_3$, TiO_2, and amorphous (carbon) broad peak. The samples appeared to have no discernible darkening on the surface. The backs of the samples, however, had a dark discoloration. The coating had a relatively smooth texture, contained a glass-like (reflective) fiber, and was 31 mil thick.

3.2.2 District 21 (Laredo)

3.2.2.1 Findings of Field Survey. Two bridges were visited in Laredo, IH 35 and Park and the Sanchez overpass and IH 35 and the Scott overpass. The former has experienced discoloration of concrete coatings while the latter has exhibited peeling of coatings. Rubbing of darkened areas was found to actually remove the dark surface, leaving a lighter colored surface beneath. It was reported that all coated concrete elements were cast-in-place, and that the coating on both overpasses was probably Tec-Kote® material, applied by Tex Hood in the period from 1979 through 1981.

3.2.2.2 Results of Analysis of Samples Taken. Two dark coating samples were taken at Park and the Sanchez overpass, and one sample with no discoloration was taken at the Scott overpass. Neither infrared analysis nor x-ray diffraction was performed on the samples. Visual analysis showed that the coating of the first two samples had a rough texture and was possibly applied over dirty concrete. The coating was indicated to be Texcoat material. The other sample was chipped off with the concrete. It had no discoloration and very little or no texture.

3.2.3 District 16 (Corpus Christi)

3.2.3.1 Findings of Field Survey. Three bridge structures were surveyed in this district. The first structure is located in Gregory, where SH 35 overpasses US 181. The other two are at the intersections of IH 37 with the Tuloso underpass and Suntide Road. Two major observations were made:

(1) Darkened material appeared to be either dust or vehicle emissions since it washed off with soap and water.

(2) Where concrete texture was smooth no darkening occurred, but as roughness of texture increased so did the darkening.

Other observations were that the south side of the first structure, the intersection of SH 35 with SH 181, was not as darkened as the north side, and that the darkened color was more brownish-gray than black. The darkening generally occurred only on textured surfaces (Fig 3.3). A sponge and 409® cleaner removed darkened material off this structure while a dry sponge did not (Fig 3.4). On the other hand, both wet and dry sponges removed darkened material off the other two bridges. The discoloration could easily be cleaned off the Tuloso underpass on IH 37 with 409® and a sponge (Fig 3.5).

3.2.3.2 Results of Analysis of Samples Taken. At the intersection of SH 35 and US 181, a coating sample with concrete was chipped off the concrete at the bridge's center pier just west of the crossover. Neither infrared analysis nor x-ray diffraction was performed on this sample. The visual analysis revealed that the sample appeared to be dark gray in color and have small texture. Two other samples were taken at the south side of the east end of the Tuloso underpass and the west side of the south end of the Suntide road overpass. No coating was evident on the surface. The analysis re-

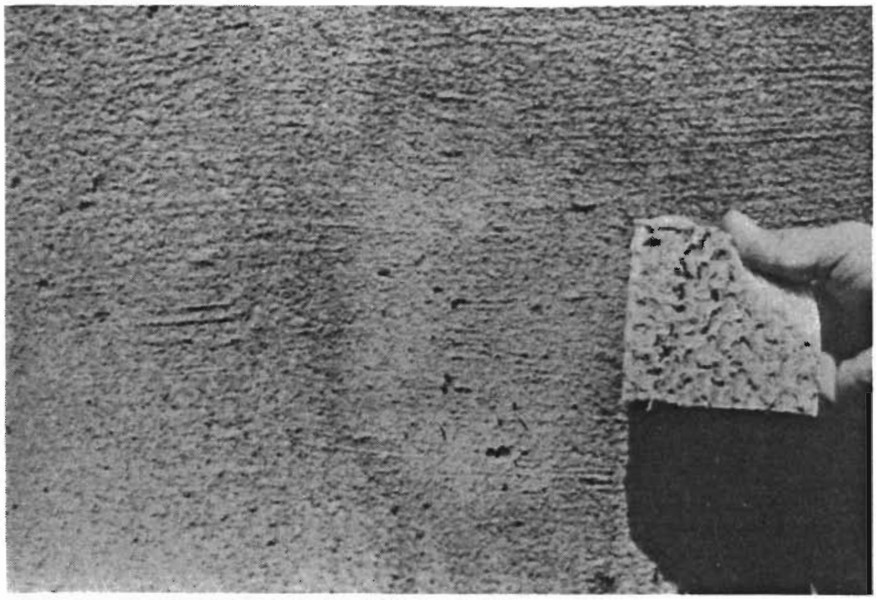


Fig 3.3. Pier after cleaning with 409® cleaner (SH 35).

vealed similar results for both samples: the material had no texture, and discoloration appeared to be from exhaust emissions, because of the high carbon content found in the samples.

3.2.4 District 2 (Fort Worth)

3.2.4.1 Findings of Field Survey. Four sites were inspected in the Fort Worth area: the intersection of IH 35 W and the Ripy Street overpass, IH 35 W south of the intersection with IH 20, the intersection of Abram Street and the SH 360 overpass, and the intersection of IH 20 and the SH 287 overpass. At the intersection of IH 35 and Ripy Street overpass, darkening of the surface was observed. It was noticed that coatings were generally darker as coarseness of surface texture increased. Darkened material could be removed from the surface with either wet or dry rags (Fig 3.6). In addition, darkened areas appeared much too random to be caused by a spray pattern. The painting contractor was consulted and indicated that the coating may have been subject to freezing temperature and/or had aged excessively.

At the IH 35 W site, south of the intersection with IH 20, some median barriers had experienced peeling of coatings in some areas (Fig 3.7). It was reported that both peeled and unpeeled areas were sprayed with the same type of coating. The only difference was that peeled areas were sprayed twice (one month between applications) resulting most likely in an overall thicker coating. District personnel feel that perhaps the thicker coating was a contributing factor.

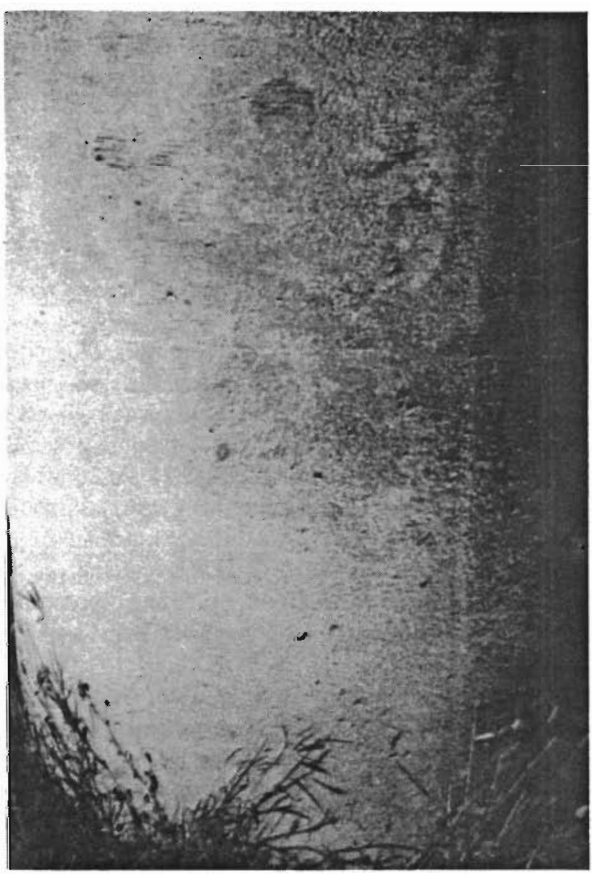
At the intersection of Abram Street and the SH 360 overpass, the left median barriers, located close to the roadway, did not have black and white patterns; they were simply solid black. The right barriers, separated from the roadway by a shoulder, were lighter in color, with some spotted, darkened areas.

The coating on the bridge at the intersection of IH 20 with SH 287 was in good condition even though it was said to be older than the previous structures.

These were the general comments by the District personnel contacted:

(1) The coatings in distress throughout the district were all applied between 1979 and 1982. Those applied before or after do not appear to be having problems.

(2) Both members with and without curing compound were turning dark.



Note the contrast between smooth surface (lower left) and rough texture

Fig 3.4. Pier on bridge on SH 35.

Fig 3.5. **Discoloration cleaned off Tulosa Underpass.**

Fig 3.6. Discoloration removed from Ripy Overpass.

3.2.4.2 Results of Analysis of Samples Taken. Two coating samples were obtained from the Fort Worth area. The first sample was taken off a concrete structure on southbound IH 35 near Garden Acres Drive. From infrared analysis, the coating was found to be a typical alkyd resin. From x-ray diffraction, the compositions were $CaCO_3$, TiO_2, and amorphous (carbon) broad peak. The visual analysis revealed that the sample had no discernible darkening on the surface, but it had a yellowish discoloration on the back. The coating had a relatively smooth texture, contained a glass-like (reflective) fiber, and was 18 mil thick.

The other sample was chipped off with the concrete at the intersection of Abram Street and the SH 360 overpass. The analysis showed that the coating had discoloration associated with a heavy texture. It also showed that the coating seemed to have been applied over dirty concrete, or that the dirt had gone through the coating. In fact, the dirt had permeated about 1/8 to 1/4 in. into the concrete. Nevertheless, there was no adhesion problem between coating and concrete. The concrete showed silica gel or latex film at the break on the back of the concrete sample. It could be that the sample was taken off a latex patch in the structure. Therefore, the observations may not have any meaning with respect to the coating over a normal concrete surface.

(3) Both precast and cast-in-place concrete members were turning dark.

(4) The bridges in Fort Worth have darkened very gradually with time, often without its becoming apparent for one to two years. This supports the idea that the darkened material is in fact exhaust emissions or dust collecting over time.

3.2.5 District 12 (Houston)

3.2.5.1 Findings of Field Survey. Several miles of median barriers were surveyed in Houston. At the intersection of Wheeler Road and SH 288, it was observed that the median barriers on the side closest to traffic had experienced darkening of coating only at the ends (the last 10 percent); the coating was applied around 1981. Also, there seemed to be a dramatic correlation between

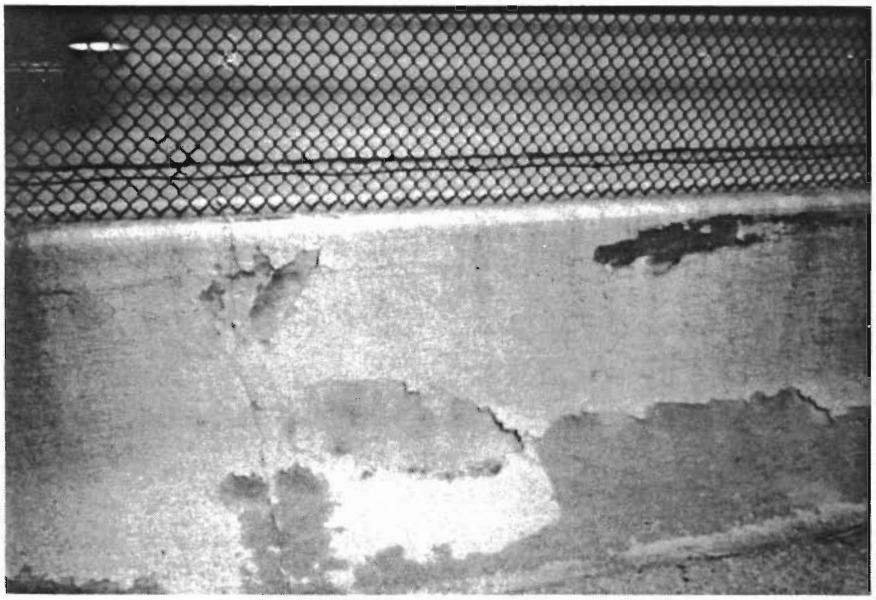


Fig 3.7. Peeling on median barrier on I 35W south of Fort Worth.

roughness of coating surface and darkness of discoloration. The darkened area extended only to the point where the rough texture terminated; the smooth, nontextured surface exhibited no darkening (Fig 3.8). A close-up view of the intersections of smooth and textured surfaces is shown in Fig 3.9. (The painting contractor indicated that the ends had a rougher texture because they were repainted.) It was found that the darkened areas could be easily cleaned with 409® cleaner and a sponge (Fig 3.10).

At the intersection of Dallas-Pierce Avenue and the SH 288, the coating of the median barriers on the left side of the northbound lanes was found to have a generalized "zebra-stripe" effect (Fig 3.11). The darkened areas appeared to correspond to the heavier texture, apparently caused by overlapping applications of coating during spraying. Throughout other locations, darkened coatings, especially those with smooth texture, were reported to have become lighter with time. It is believed that rain has washed some of the darkened material off these surfaces.

3.2.5.2 Results of Analysis of Samples Taken. A coating sample was chipped off with the concrete from a dark area at the intersection of Dallas-Pierce Avenue and SH 288. The analysis revealed that the sample had probably been taken off a latex patch in the structure. The results of the analysis of this sample were similar to those of the sample taken at the intersection of Abram Street and the SH 360 overpass in Fort Worth.

3.2.6 District 4 (Amarillo)

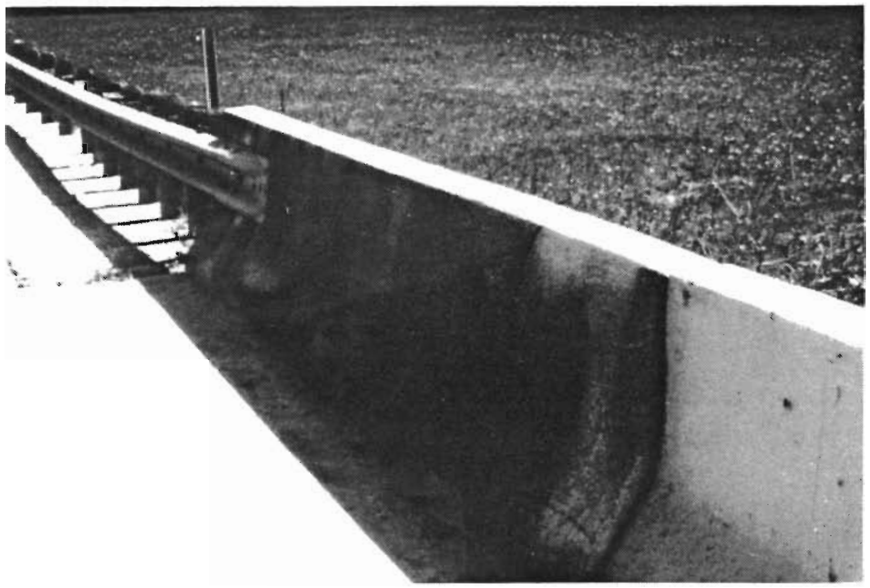
3.2.6.1 Findings of Field Survey. Several miles of median barriers on different highways were inspected in Amarillo. No severe darkening was observed. However, peeling of the coating was found to be a major problem (Fig 3.12). Peeling had occurred only in those concrete structures where curing compound was used. It was reported that generally the curing compound was applied the same day the concrete was placed and that no provision was made to remove the compound before the coating was applied. It was also reported that all median barriers in the Amarillo area are slip-formed with no form oil used; still, barriers with and without peeling were found. Particular observations were made at each site visited, as follows.

(1) Median barriers on IH 40 from Station 159 to 231 (*east of Airport Road*) showed severe peeling of coating. The barriers were coated in December, 1980. It is believed that Tex Hood did spray these barriers and that the coating was Tec-Kote®. The curing compound application was reported to have been extra heavy. About one and one-half years had passed when large portions of the coating on both sides of barriers began peeling. Even at the time the survey was made (September 1986), a yellow colored material (presumably curing compound) could still be seen on the backs of the peelings.

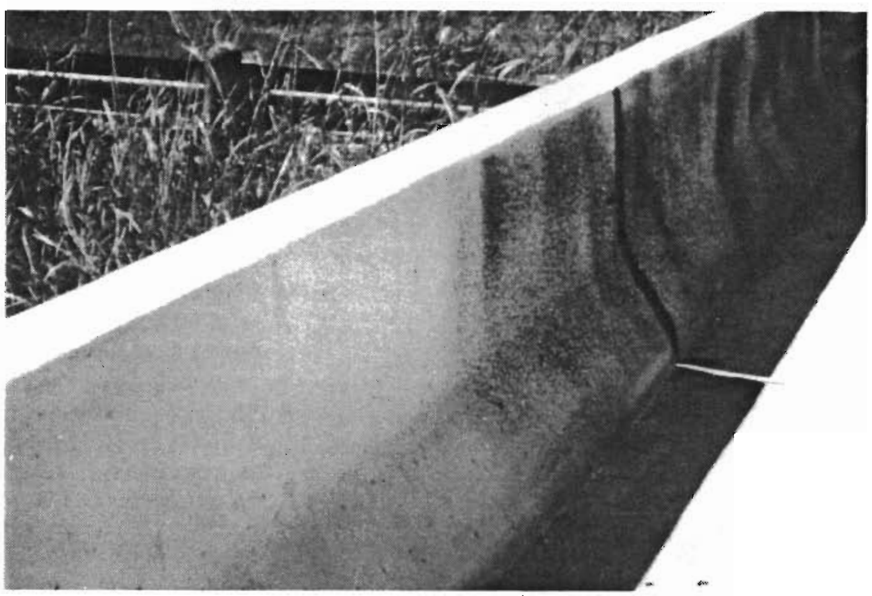
(2) Median barriers on IH 40 *west of Airport Road* (up to the Sante Fe Bridge) were found to be in excellent condition with no peeling occurring. The barriers were coated in 1983, presumably with the same coating as that described above. The only difference was that half the recommended amount of curing compound was used as when the concrete was placed. It is to be noted that median barriers both east and west of Airport Road experienced the same weather and the same traffic.

(3) Median barriers on IH 27 underneath the 19th Street overpass (the IH 40 interchange) were coated around October, 1984. Peeling occurred within one year on both sides of the median. Tex Hood did not coat these barriers. A curing compound, Waxahachie (Secure Inc.), was reported to have been used on these barriers.

Currently, the specifications recommend a minimum value of 180 ft^2/gal when curing compounds are applied but do not list a maximum value which can be used. The District personnel contacted recommended that if a coating is to be applied later, a maximum value for the amount of curing compound should be specified.



(a) **Discoloration on north end of west side of barriers with textured coating (SH 288 in Houston).**



(b) **Discoloration on south end of west side of barriers with textured coating (SH 288 in Houston).**

(Continued)

Fig 3.8.

3.2.6.2 Results of Analysis of Samples Taken. A light-colored coating sample was obtained from the IH 40 site east of Airport Road. From infrared analysis the sample was found to be typical alkyd resin. The analysis of material on the back of the coating sample indicated possible Type II (white pigmented) curing membrane. From X-ray diffraction, the compositions were shown to be $CaCo_3$, TiO_2, and amorphous (carbon) broad peak. The visual analysis indicated that the sample had no discernible darkening on the surface. The back, however, had a yellowish discoloration. The coating had a relatively smooth texture, contained a glass-like (reflective fiber), and was 16 mil thick.

A dark coating sample was taken at a third site (IH 27). The results of the infrared analysis and X-ray diffraction were similar to those described for the previous sample, except that the material on the back was found to be laitance. The visual analysis indicated that this coating had a dark gray color associated with a rougher texture. The coating was 22 mil thick.

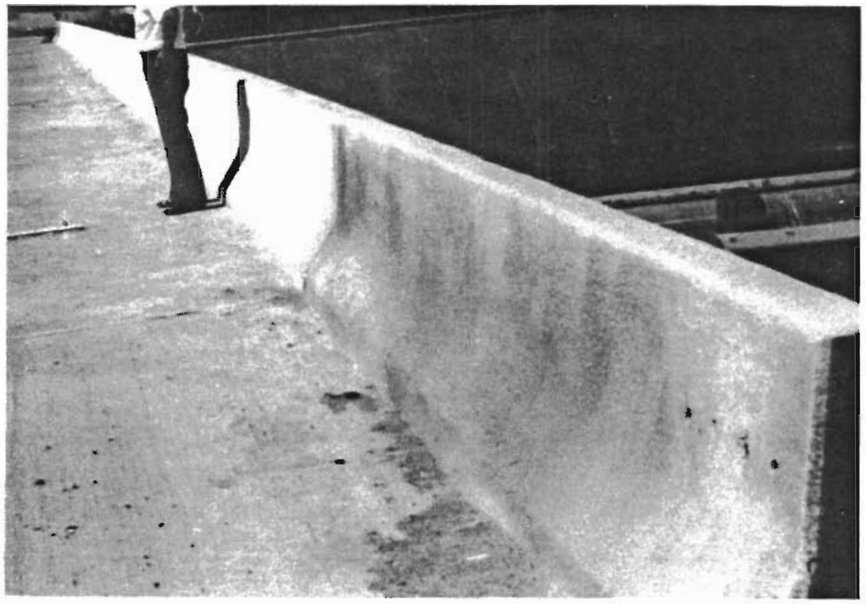
3.2.7 District 19 (Atlanta)

It was reported hat some coatings in the Atlanta area had experienced both darkening and peeling. A bridge on US 59 in Marion county, located near the town of Jefferson, over Big Cypress Creek, had shown discoloration of the coating on the west side while the coating on the east side was in good condition. In Texarkana, the coatings applied on the precast units of median barriers on US 59 were reported to have flaked off, whereas those applied on the cast-in-place units were still in good condition. No sample was obtained.

3.3 SUMMARY OF FINDINGS

Several observations can be drawn from the findings of the field surveys supported by the results of the analyses performed on the field samples.

(1) Both darkening and peeling of concrete coatings have been experienced in Texas Districts, particularly on concrete bridges and median barriers.



(c) **Discoloration on north end of east side of barriers with textured coating (SH 288 in Houston).**

Fig 3.8 (Continued).

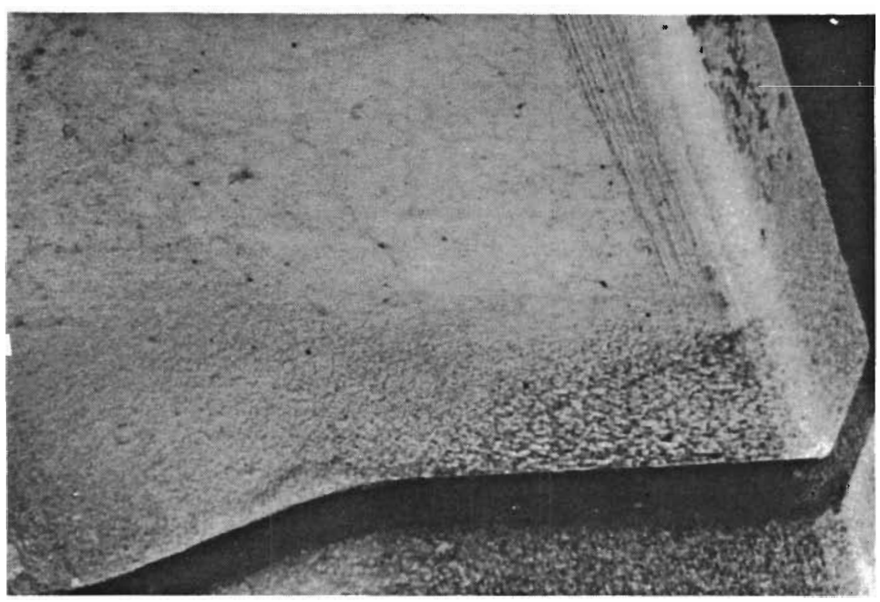


Fig 3.9. Close-up of intersection of smooth and textured surfaces.

(2) Darkening was reported to have been caused mainly by dust and vehicle exhaust emissions collecting on coating surfaces.

(3) Darkened material could be removed by the application of soap and water or a wet sponge, with 409® cleaner and sponge, and sometimes with a dry rag.

(4) Rough coating surfaces were found to have experienced more darkening than smooth ones.

(5) There were cases where spray patterns seemed to have contributed to darkening of coating surfaces (in San Antonio and Houston); apparently the coating was overlapped. In other cases, darkened areas were too random to be caused by spray patterns (in Fort Worth).

(6) Median barriers located close to roadways were observed to have experienced much more darkening (some were nearly black) than those separated from roadways by shoulders.

(7) Number of coating applications was found to be a possible factor in causing peeling (in Amarillo surfaces sprayed twice began peeling although no connection was found between peeling and thick single-coating applications.)

(8) Members both with and without curing compound were observed to be turning dark.

(9) The application of curing compounds on concrete surfaces was indicated to be a factor contributing to peeling. In fact, there was a case (in Amarillo) where peeling occurred only in structures with curing compounds. Also, it was reported that the greater the rate of the use of curing compound, the more severe the peeling of coatings was.

(10) Both precast and cast-in-place members were observed to be turning dark (in Fort Worth).

(11) Slipformed members were reported to be experiencing more peeling problems.

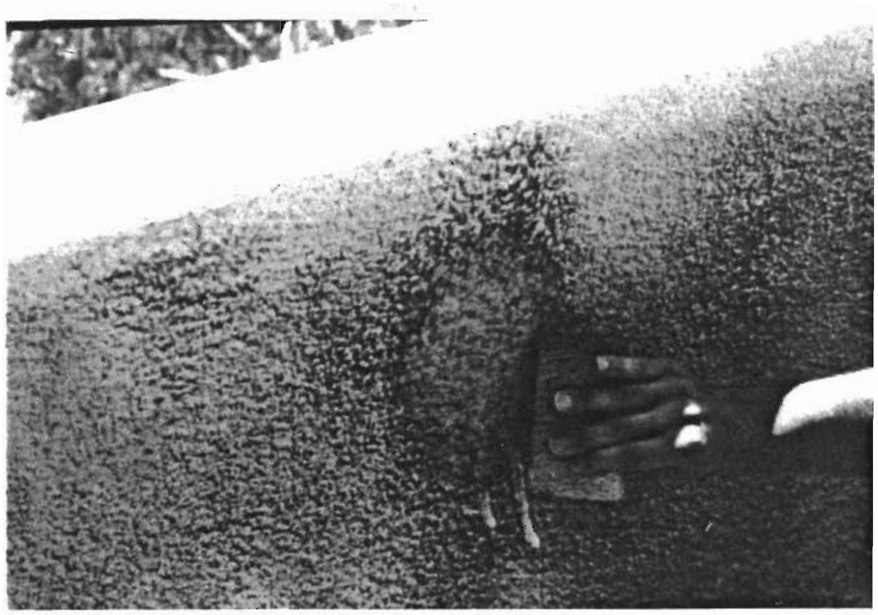


Fig 3.10. Cleaning discolored areas on SH 288.

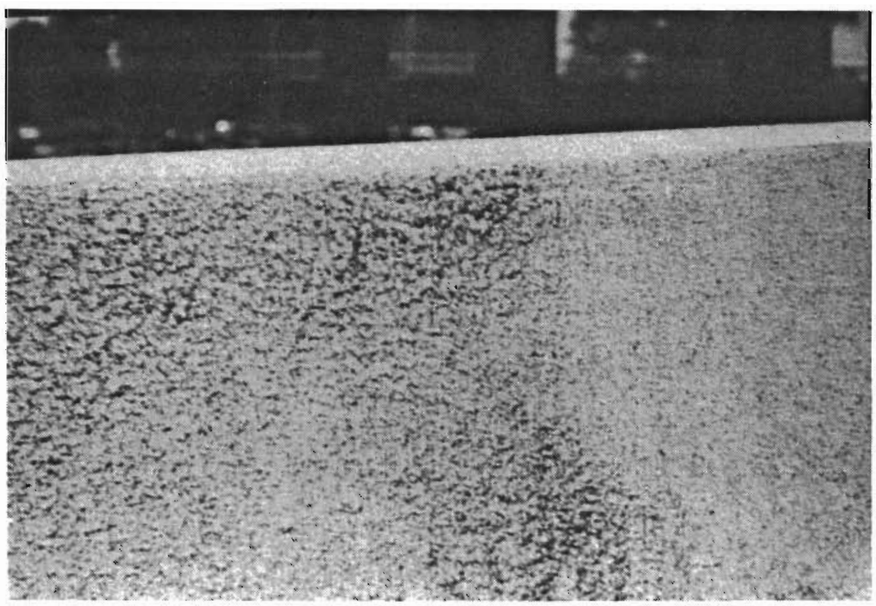


Fig 3.11. Zebra-stripe effect on barrier on SH 288.

(12) Inferences could not be made as to whether "age of concrete when coating was applied" had any bearing on darkening or peeling of coatings.

(13) Finally, it seemed that the Tec-Kote® material has exhibited unsatisfactory performance in most of the surveyed Districts.

Fig 3.12. Peeling on median barrier in Amarillo.

CHAPTER 4. TEST PANEL PROGRAM

4.1 BACKGROUND

The surveys discussed in the previous chapters indicate several variables that are major contributors to darkening and peeling of concrete coatings. A test panel program was developed to evaluate many of the variables which affect coating performance. The test program was developed in consultation with the Technical Advisor. Sixty test panels were constructed to account for the large number of variables and the potential interaction between each pair of these variables. The panels were 12 in. x 12 in. x 1-1/2 in. and consisted of normal portland cement concrete having about a 6-in. slump. All of the panels were coated with one coat on the same day. The coatings were applied by a private contractor who has coated many of the highway structures in Texas (Fig 4.1).

Fig 4.1. Application of coatings to test panels.

4.2 TEST VARIABLES

4.2.1 Type of Coating

Due to the large number of concrete coatings available on the market, some discrimination had to be used to determine which coatings should be incorporated into the test. The two concrete coatings currently approved by the state of Texas, Prestonshield® and Secoat W®, were included in the test, along with several other coatings which may be approved at a later date.

4.2.1.1 Prestonshield®. Prestonshield is an alkyd-based product made by Preston Pacific and is currently on the list of concrete coatings approved for the state of Texas.

4.2.1.2 Thorocoat®. Thorocoat is an alkyd-based product made by Thoro System Products Inc. and is currently not on the approved list of concrete coatings for the state of Texas. It is, however, a product highly endorsed by other states.

4.2.1.3 Tec-Kote®. Tec-Kote is an alkyd-based product which was made by TCI and for a period of time was on the list of concrete coatings approved for the state of Texas. Tec-Kote® was used throughout Texas and is one of several coatings which have sustained subsequent darkening or peeling difficulties. It should be noted that Tec-Kote® was taken off the approved list not because it failed to pass any of the SDHPT standards but simply because TCI chose to make investments in other products.

4.2.1.4 Secoat W®. Secoat W is an acrylic water-based coating made by Secure and is currently on the approved list of concrete coatings for the state of Texas.

4.2.1.5 Highway Department #742. This product, a styrenated acrylate-based coating, is currently approved as a coating for steel structures in the state of Texas. It is being considered for use on concrete structures because of its quick drying characteristics. One of the problems currently encountered with most concrete coatings is that during spraying some of the coating spray gets on passing vehicles. Coating # 742 dries so quickly that it reduces the likelihood of adhesion to passing vehicles which may encounter the spray.

4.2.2 Coating Texture

A wide variety of texturing materials can be added to concrete coatings. The amount of texture appears to have a significant effect on how much darkening will occur on a concrete surface. Throughout the entire state of Texas a consistent pattern was observed indicating that as surface texture became rougher the tendency towards darkening increased. The findings in Chapter 3 indicate that the dark material obtained from coating samples was a carbon substance essentially the same as vehicle emissions. It seems reasonable that a rough surface would collect exhaust particles more easily than a smooth one and that a rough surface would be less likely to be cleaned during a rain. For this reason, two different levels of textures were used: rough and smooth. The rough texture was produced by adding vermiculite to the coating.

4.2.3 Concrete Texture

Because texture was thought to be an important factor in producing darkening some panels were constructed with various amounts of texture on the surface but with no coatings applied. If uncoated panels tend to darken it would support the theory that surface texture is a very important variable. The four concrete surface textures are described below.

4.2.3.1 Rough. This type of texture was produced by brushing the surface of the concrete panel with a wire brush when the concrete was partially cured. No coatings were applied to this type of surface. The sole purpose of these panels was to determine if darkening would occur on a rough surface without a concrete coating.

4.2.3.2 Medium. This type of texture was produced by brushing the surface of the concrete panel with a wire brush when the concrete was partially cured, as previously discussed. The difference was that the surface was not brushed as vigorously and was therefore not as rough. As before, these panels served as controls and thus had no coatings applied to them.

4.2.3.3 Smooth. This type of texture was produced by troweling the concrete surface. Approximately 92 percent of the panels coated applied to this type of concrete texture, since it is very similar to the kind of surface to which coatings are applied in actual construction.

4.2.3.4 Slipform. These panels were constructed using plastic coated plywood. The resulting surface is very similar to the surface produced by slipforms, which are often used for cast-in-place median barriers. Approximately 8 percent of the panels coated had this type of concrete texture.

4.2.4 Age of Concrete When Coated

Panels were made to determine if moisture in the concrete during early curing had any visible effects on the coating performance. As concrete cures, moisture evaporates from the surface. It was suggested that the pressure due to the water vapor on the coating film could cause peeling. Since the rate of curing is a function of the age of the concrete, the panels were divided into two groups, some having a concrete age of twelve days and the remainder having an age of thirty-five days. The minimum age of twelve days was chosen since it is highly unlikely for concrete to be coated before this time.

4.2.5 Proximity to Highway

Virtually all of the coating problems experienced thus far have occurred in areas of high traffic volume. To help determine whether coating distress actually is a function of traffic volume, test panels were placed in one of two locations. Approximately 92 percent of the panels were placed in the high traffic environment of the interstate highway system (Fig 4.2). The average daily traffic for this area was about 140,000 vehicles. Approximately 8 percent of the panels were placed on the roof of a building at the SDHPT Camp Hubbard complex in Austin, Texas. These panels were several hundred feet from traffic.

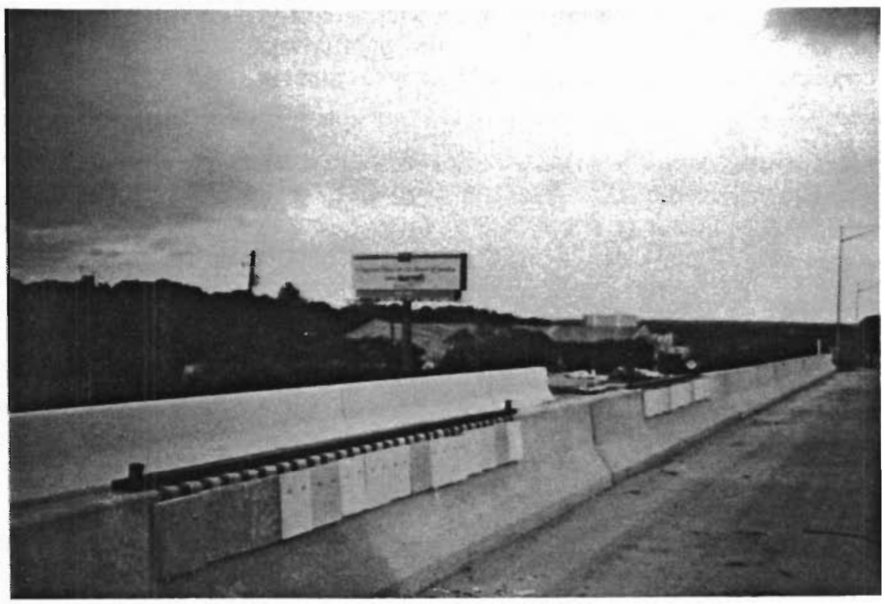


Fig 4.2. Panels in high traffic environment.

4.2.6 Thickness of Coating

Several districts reporting darkening and peeling problems have suggested that the thickness of the coating may be a factor. The thicker coating takes longer to dry and thus leaves a moist surface to which dirt can adhere. It has been reported that in some cases a fingernail impression can be made on the coating long after it should have dried. If a texturizing material is used, then a thicker coat may increase the concentration of the textured particles on the finished surface. This can increase the capacity of the textured coating to collect dust particles. Indeed, several of the districts have examples of darkened structures on which it appears that the spraying pattern can be seen. In areas where the spray has overlapped, the coating appears darker, and in areas where there is no overlap, the coating appears lighter. The test panels were sprayed with one of two coating thicknesses: normal and extra heavy.

4.2.7 Surface Preparation

Some panels were made to determine how surface preparation affected bonding between the concrete and the coating. Peeling is the result of poor bond between the coating and the concrete. During the construction process a variety of chemicals (including water) may come in contact with the concrete surface and any one of these or a combination thereof may initiate peeling in the coating at a later time.

4.2.7.1 Clean Surface. To have a basis for comparison, coatings were applied to seventeen test panels with clean surfaces, which served as the control in the experiment. For this test "clean" was used to describe panel surfaces which were dry, free of curing compound, form oil, or laitance.

4.2.7.2 Clean and Damp Surface. There has been some speculation that if concrete coatings were applied too soon after a heavy rainstorm, there would be a weak bond between the coating and the damp concrete. To model this type of situation, panels were soaked in water for twenty-four hours and then removed from the water and allowed to dry only until the surface appeared dry, whereupon the panels were sprayed with a coating. It was assumed that coatings are not applied in practice until the surface of the concrete at least appears to be dry.

4.2.7.3 Curing Compound. It was observed in Amarillo that when curing compound was applied in excessive quantities and concrete coatings were later applied, the coating will eventually peel in less than two years. At the time the observations were made, remnants of curing compound could be seen on the backs of the peeled portions. In the laboratory, type two curing compound (white pigment) was applied to the surfaces of seven test panels. The purpose of this portion of the test was to determine what happened if curing compound was used and no attempt was made to clean it off. In this test, curing compound was applied according to the SDHPT recommended rate of 21 cc/ft^2.

4.2.7.4 Form Oil. Nox Crete form oil was applied to the surface of nine test panels. This was to model the effect of the use of form oil if no attempt were made to clean it off. The form oil was applied according to the manufacturer's recommended rate of 12 cc/ft^2.

4.2.7.5 Half Form Oil. Nox Crete form oil was applied to eight test panels in a manner similar to that described above but at half the application rate. This was to model the effect of what happens if form oil were used and a poor attempt were made to clean it off.

4.2.7.6 Laitance. Laitance is the paste-like substance on the surface of concrete after the concrete cures. It is usually white and feels somewhat like chalk dust. In all SDHPT projects, contractors are required to remove this film before applying a concrete coating because it will interfere with the bond between the coating and the concrete. Concrete with high slump (about 6 in.) was used for the test panels so that a significant amount of laitance would develop on the concrete surface.

4.2.7.7 Clean Surface. It has been proposed that, because median barriers have a slightly concave surface shape, the concrete coating may tend to lift off the surface when it shrinks instead of merely producing hairline cracks. Four panels were constructed with a concave surface so that this type of behavior could be examined.

4.3 TEST SCHEDULE

A summary of the test variables described is shown in Fig 4.3. Because a large number of variables exists it was decided that combinations of variables should be tested simultaneously so as to minimize the required number of test panels. Using the notation shown in Fig 4.3, a description of each of the test panels is shown in Fig 4.4. As can be seen, no two panels are alike, although panels contain each of the variables. It should be noted that panels 48 through 52 have no coating on them at all so as to act as a control for the test.

A. Type of Coating
   1. Preston Shield 1200
   2. Thorocoat
   3. Tec-Kote
   4. Secoat W
   5. Highway Dept. #742

B. Coating Texture
   1. Rough
   2. Smooth

C. Concrete Texture
   1. Rough
   2. Medium
   3. Trowelled
   4. Slipform

D. Age of Concrete when Coated
   1. 12 days
   2. 35 days

E. Proximity to Highway
   1. Heavy Traffic
   2. No Traffic

F. Thickness of Coat
   1. Normal
   2. Extra Heavy

G. Surface Preparation
   1. Clean Surface
   2. Clean Surface but Damp Concrete
   3. Curing Compound
   4. Form Oil
   5. Less Form Oil
   6. Laitance
   7. Clean with Concave Surface

Fig. 4.3. Summary of Test Variables Used in Test Panel Program

4.4 TEST PANEL MONITORING

4.4.1 Colorimeter Tests

At three-month intervals starting after six months of exposure to the traffic environment, each of the test panels was removed from its mount and brought to D-9 for a color test. The test is based on Texas SDHPT Test Method Tex-839-B and has been shown to give accurate, repeatable results for flat uniform surfaces. In this way the subtle, gradual darkening of the test panels could be recorded.

4.4.2 Visual Inspection

The panels were visually inspected at regular three-month intervals and checked for peeling, cracking, and other signs of distress.

Panel Test #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Coating	1	2	3	4	5	3	1	2	3	4	5	2	1	2	3
B. Coat Text.	1	2	2	1	2	2	2	2	1	1	2	1	2	1	1
C. Conc. Text.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
D. Age	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
E. Proximity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
F. Thickness	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G. Surface	1	2	3	4	5	6	1	1	2	3	4	5	6	2	1

Panel Test #	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A. Coating	4	5	1	1	2	3	4	5	4	1	2	3	4	5	1
B. Coat Text.	2	2	1	1	1	2	1	2	2	1	2	1	1	2	1
C. Conc. Text.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
D. Age	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
E. Proximity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
F. Thickness	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
G. Surface	2	3	4	5	6	4	1	2	3	4	5	6	4	1	2

Panel Test #	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
A. Coating	1	2	3	4	5	4	1	2	3	4	5	5	1	2	3
B. Coat Text.	2	1	1	2	2	1	2	1	2	1	2	2	1	2	1
C. Conc. Text.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
D. Age	1	2	1	2	1	2	1	2	1	2	1	2	1	1	1
E. Proximity	1	1	1	1	1	1	2	1	2	1	1	2	1	2	1
F. Thickness	1	1	1	1	2	1	1	1	1	1	2	2	2	2	2
G. Surface	3	4	5	6	5	1	2	3	4	5	6	6	1	2	3

Panel Test #	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
A. Coating	4	5	-	-	-	-	-	1	2	3	4	1	2	3	4
B. Coat Text.	2	2	-	-	-	-	-	2	2	2	2	2	2	2	2
C. Conc. Text.	3	3	1	3	1	2	3	4	4	4	4	4	4	4	4
D. Age	2	1	2	2	2	2	2	2	2	1	2	1	1	1	1
E. Proximity	2	1	2	2	1	1	1	1	1	1	2	1	1	1	2
F. Thickness	2	2	-	-	-	-	-	1	1	1	1	1	1	1	1
G. Surface	4	5	1	1	1	1	1	1	1	1	1	7	7	7	7

Note: (a) Reference numbers are described in Fig 4.3.
(b) Panels 48 through 52 had no coatings applied, to see whether or not darkening is due strictly to surface texture.

Fig 4.4. Descriptions of test panels.

CHAPTER 5. ANALYSIS OF TEST PANEL MONITORING DATA

5.1 RESULTS OF COLORIMETER TESTS AND VISUAL INSPECTION

Initial colorimeter readings were obtained for all test panels in October 1986. After six months of exposure to the traffic environment, colorimeter tests and visual inspections were performed on the panels at regular three-month intervals (all of the evaluations are presented in the Appendix). The last colorimeter test was performed in October 1987 after one year of exposure. One of the control panels, No. 37, had been damaged during transport, before the initial colorimeter readings could be obtained. Another panel (No. 7) from those that were placed in the high traffic environment was also damaged, during the course of testing. Two panels (Nos. 53 and 57) were removed in July because severe peeling had begun.

After the one-year colorimeter readings had been obtained, all panels, including the controls, were thoroughly inspected and checked for darkening, peeling, cracking, and other signs of coating distress. Slides were taken of almost all panels and later reviewed to see whether the appearance or condition of the panels confirmed the quantitatively-based results of the colorimeter tests. Coating conditions were then determined, based on both colorimeter readings and visual inspections.

Table 5.1 gives the coating conditions for each of the test panels that was placed in the high traffic environment, based on the difference between the initial and one-year colorimeter readings and the visual inspection of panels. These criteria were used in interpreting the colorimeter results.

(1) If $DY \geq 10$, a panel was considered to be showing significant darkening.
(2) If $DY \geq 5$ and either of Dx or Dy exceeded 0.005, a panel was also considered to be showing significant darkening.
(3) If $5 < DY < 10$ and neither Dx nor Dy exceeded 0.005, a panel was considered to be showing trends towards darkening.
(4) If $DY \leq 5$, the difference was considered to be due to testing and panel location variations.

It should be noted that DY is a measure of discoloration and Dx and Dy are indications of yellowing. It should be observed that even when the mininum is met for criterion No. 1 (DY = 10), the darkening is rather mild compared to many cases of darkening found in the field. The criterion is arbitrary. As a reference, Fig 5.13 shows a panel with DY = 11.6.

The panels superscripted with "a" were removed from their mounts and brought to D-9 when severe peeling of coatings was observed. The peeling occurred after less than six months of exposure to the high traffic environment.

The panels superscripted with "b" are those which were judged by subjective visual inspection to show darkening and which had values of ΔY, Δx, and Δy that essentially satisfied the darkening criteria mentioned above. For instance, panel No. 17 had a ΔY of 4.8 associated with both Δx and Δy exceeding 0.005. The darkening was judged significant because colorimeter results essentially satisfied the second criterion mentioned above, and because the discoloration was similar to that of panel No. 35, which clearly met the criteria and which had almost the same combination of test variables.

Among the 50 panels listed in Table 5.1, it was found that

(1) 17 panels (34 percent) experienced significant darkening,
(2) 18 panels (36 percent) showed trends towards darkening,
(3) 15 panels (30 percent) exhibited no significant indication of darkening,
(4) only two panels, No. 53 and 57, experienced severe peeling of coatings on a large portion of thesurface, and
(5) two panels, No. 54 and No. 55, began to show some whitish material, apparently lime or laitance, about 2 inches wide along the periphery.

Table 5.2 shows an analysis of the control panels. The findings can be summarized as follows:

(1) two panels, No. 46 and No. 56, started to show trends towards darkening,
(2) blistering of the coating was observed in panel No. 56, possibly caused by the formation of lime on the concrete surface (which could eventually result in peeling of coating),
(3) from colorimeter analysis, panel No. 39 (coated with Tec-Kote®) exhibited trends towards darkening.

However, from a visual inspection, the panel appeared to be much lighter in color (nearly white) than any of those with the same coating which were exposed to the traffic environment.

5.2 EFFECT OF TEST VARIABLES

Figures 5.1 to 5.6 illustrate the different combinations of test variables for each coating type used. The figures are used to draw inferences on the effect of each test variable as well as combinations of variables to determine what variables are likely to contribute to coating distresses. The legends and superscripts used to describe the panel condition are

TABLE 5.1 COATING CONDITIONS OF TEST PANELS PLACED IN THE HIGH TRAFFIC ENVIRONMENT BASED ON THE RESULTS OF COLORIMETER TESTS AND VISUAL INSPECTION

Panel	Type of	Texture of	Initial Readings			One-Year Readings			Difference			
I.D	Coating	Coating	Y	x	y	Y	x	y	ΔY	Δx	Δy	Comments
1	Preston	Rough	44.0	0.321	0.330	37.9	0.325	0.334	6.1	0.004	0.004	ST
2	Thorocoat	Smooth	32.3	0.325	0.336	23.0	0.338	0.338	9.3	0.003	0.002	ST
3	Tec-Kote	Smooth	37.1	0.327	0.338	35.1	0.325	0.333	2.0	0.002	0.005	-
4	Secoat W	Rough	36.4	0.327	0.334	25.0	0.328	0.336	11.4	0.001	0.002	SD
5	#742	Smooth	39.9	0.310	0.322	34.2	0.316	0.325	5.7	0.006	0.003	SD
6	Tec-Kote	Smooth	35.9	0.328	0.338	34.9	0.326	0.334	1.0	0.002	0.004	-
7	Preston	Smooth	48.8	0.321	0.330	Panel was damaged						-
8	Thorocoat	Smooth	33.5	0.325	0.336	25.8	0.327	0.337	7.7	0.002	0.001	ST
9	Tec-Kote	Rough	31.7	0.324	0.337	36.1	0.324	0.335	4.4	0.000	0.002	-
10	Secoat W	Rough	39.6	0.323	0.333	25.2	0.326	0.334	14.4	0.003	0.001	SD
11	#742	Smooth	43.4	0.312	0.323	36.5	0.316	0.327	6.9	0.004	0.004	SD[b]
12	Thorocoat	Rough	30.3	0.327	0.337	22.7	0.329	0.338	7.6	0.002	0.001	ST
13	Preston	Smooth	49.9	0.321	0.330	41.2	0.325	0.334	8.7	0.004	0.004	ST
14	Thorocoat	Rough	28.9	0.325	0.337	23.3	0.328	0.339	5.6	0.003	0.002	ST
15	Tec-Kote	Rough	37.8	0.326	0.337	35.3	0.324	0.335	2.5	0.002	0.002	-
16	Secoat W	Smooth	35.0	0.322	0.333	30.2	0.326	0.336	4.8	0.004	0.003	-
17	#742	Smooth	37.4	0.309	0.321	32.6	0.318	0.327	4.8	0.009	0.996	SD[b]
18	Preston	Rough	37.7	0.323	0.332	36.3	0.326	0.334	1.4	0.003	0.002	-
19	Preston	Rough	40.7	0.322	0.331	35.8	0.326	0.334	4.9	0.004	0.003	ST[b]
20	Thorocoat	Rough	30.1	0.327	0.337	23.7	0.329	0.339	6.4	0.002	0.002	ST
21	Tec-Kote	Smooth	36.3	0.328	0.338	34.7	0.325	0.334	1.6	0.003	0.004	-
22	Secoat W	Rough	32.4	0.325	0.335	21.3	0.328	0.336	11.1	0.003	0.001	SD
23	#742	Smooth	42.2	0.311	0.322	35.3	0.317	0.327	6.9	0.006	0.005	SD
24	Secoat W	Smooth	40.1	0.323	0.334	27.1	0.326	0.337	3.0	0.003	0.003	-
25	Preston	Rough	44.7	0.322	0.331	37.9	0.325	0.333	6.8	0.003	0.002	ST
26	Thorocoat	Smooth	31.1	0.326	0.337	23.8	0.328	0.339	7.3	0.002	0.002	ST
27	Tec-Kote	Rough	36.5	0.327	0.337	34.3	0.326	0.336	2.2	0.001	0.001	-
28	Secoat W	Rough	35.4	0.324	0.334	23.5	0.327	0.335	11.9	0.003	0.001	SD
29	#742	Smooth	41.7	0.312	0.322	29.9	0.318	0.329	11.8	0.006	0.007	SD
30	Preston	Rough	44.6	0.322	0.331	37.3	0.326	0.333	7.3	0.004	0.002	ST
31	Preston	Smooth	45.6	0.322	0.331	39.5	0.327	0.335	6.1	0.005	0.004	SD
32	Thorocoat	Rough	27.2	0.327	0.337	22.9	0.329	0.339	4.3	0.002	0.002	ST[b]
33	Tec-Kote	Rough	35.3	0.327	0.337	32.2	0.326	0.335	3.1	0.001	0.002	-
34	Secoat W	Smooth	36.2	0.323	0.334	28.9	0.326	0.337	7.3	0.003	0.003	ST
35	#742	Smooth	43.1	0.310	0.321	35.3	0.316	0.328	7.8	0.006	0.007	SD
36	Secoat W	Rough	36.2	0.324	0.335	25.3	0.327	0.335	10.9	0.003	0.000	SD
38	Thorocoat	Rough	26.4	0.326	0.337	22.1	0.329	0.339	4.3	0.003	0.002	ST[b]
40	Secoat W	Rough	32.7	0.323	0.335	27.5	0.327	0.337	5.2	0.004	0.002	ST
41	#742	Smooth	44.6	0.309	0.320	33.5	0.317	0.327	11.1	0.008	0.005	SD
43	Preston	Rough	42.5	0.322	0.321	34.8	0.327	0.335	7.7	0.005	0.014	SD
45	Tec-Kote	Rough	33.4	0.325	0.336	34.0	0.326	0.335	0.6	0.001	0.001	-
47	#742	Smooth	38.7	0.311	0.324	38.1	0.315	0.325	0.6	0.004	0.001	-
50	-	-	25.8	0.320	0.330	23.9	0.321	0.332	1.9	0.001	0.002	-
51	-	-	21.5	0.326	0.336	22.7	0.324	0.333	1.2	0.002	0.003	-
52	-	-	25.5	0.332	0.340	26.6	0.331	0.338	1.1	0.001	0.002	-
53 [a]	-	-	50.1	0.321	0.330	41.8	0.326	0.336	8.3	0.005	0.006	SD, P
54	Thorocoat	Smooth	32.6	0.326	0.336	25.1	0.329	0.338	7.5	0.003	0.002	ST, L
55	Tec-Kote	Smooth	37.9	0.326	0.336	32.7	0.325	0.336	5.2	0.001	0.000	ST, L
57 [a]	Preston	Smooth	47.8	0.321	0.330	33.7	0.326	0.336	14.1	0.005	0.006	SD, P
58	Thorocoat	Smooth	31.3	0.325	0.336	20.9	0.326	0.337	10.4	0.001	0.001	SD
59	Tec-Kote	Smooth	34.9	0.326	0.336	27.1	0.326	0.336	7.8	0.000	0.000	ST

SD: Significant Darkening
ST: Showing Trends Towards Darkening
P: Peeling of Coating
L: Laitance is evident on the Surface

[a] Panel was removed from traffic environment when peeling was observed
[b] Description of darkening condition was determined on both colorimeter analysis and visual inspection

TABLE 5.2 COATING CONDITIONS OF CONTROL PANELS BASED ON THE RESULTS OF COLORIMETER TESTS AND VISUAL INSPECTION

Panel I.D.	Type of Coating	Texture of Coating	Initial Readings Y	x	y	One-Year Readings Y	x	y	Difference ΔY	Δx	Δy	Comments
37	Preston	Smooth	Panel was damaged									
39	Tec-Kote	Smooth	41.9	0.325	0.335	47.5	0.323	0.333	5.6	0.002	0.002	ND
42	#742	Smooth	46.4	0.307	0.317	46.1	0.309	0.319	0.3	0.002	0.002	-
44	Thorocoat	Smooth	37.1	0.325	0.335	34.8	0.327	0.337	2.3	0.002	0.002	-
46	Secoat W	Smooth	49.4	0.321	0.331	42.5	0.323	0.334	6.9	0.002	0.003	ST
48	-	No Coating [a]	30.0	0.319	0.328	30.6	0.317	0.326	0.6	0.002	0.002	-
49	-	No Coating [a]	33.9	0.328	0.335	37.8	0.327	0.335	3.9	0.001	0.000	-
56	Secoat W	Smooth	48.8	0.321	0.331	43.5	0.324	0.334	5.3	0.003	0.003	ST, L[a]
60	Secoat W	Smooth	37.0	0.319	0.332	41.3	0.323	0.334	4.3	0.004	0.002	-

[a] Blistering in the coating caused by the formation of laitance or carbon hydroxide

ND: No sign of darkening according to the visual inspection
ST: Showing trends toward darkening
L: Laitance or carbon hydroxide forming beneath the coating film

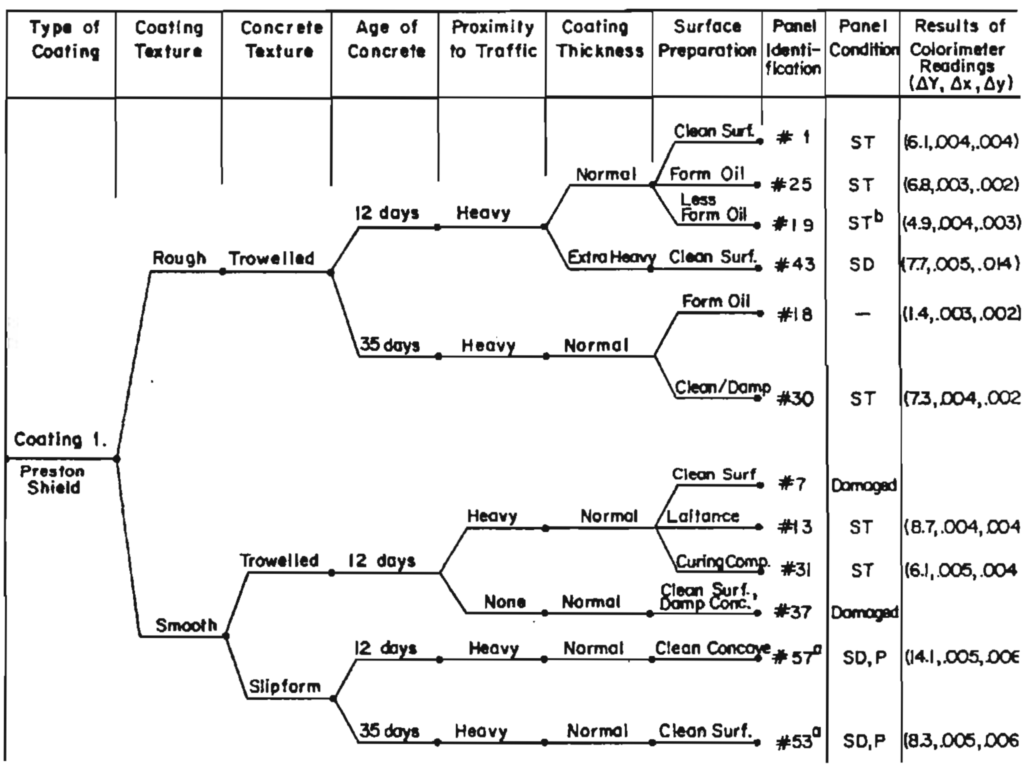


Fig 5.1. The results of the exposure test on test panels coated with Prestonshield® (legend for panel conditions given in section 5.2).

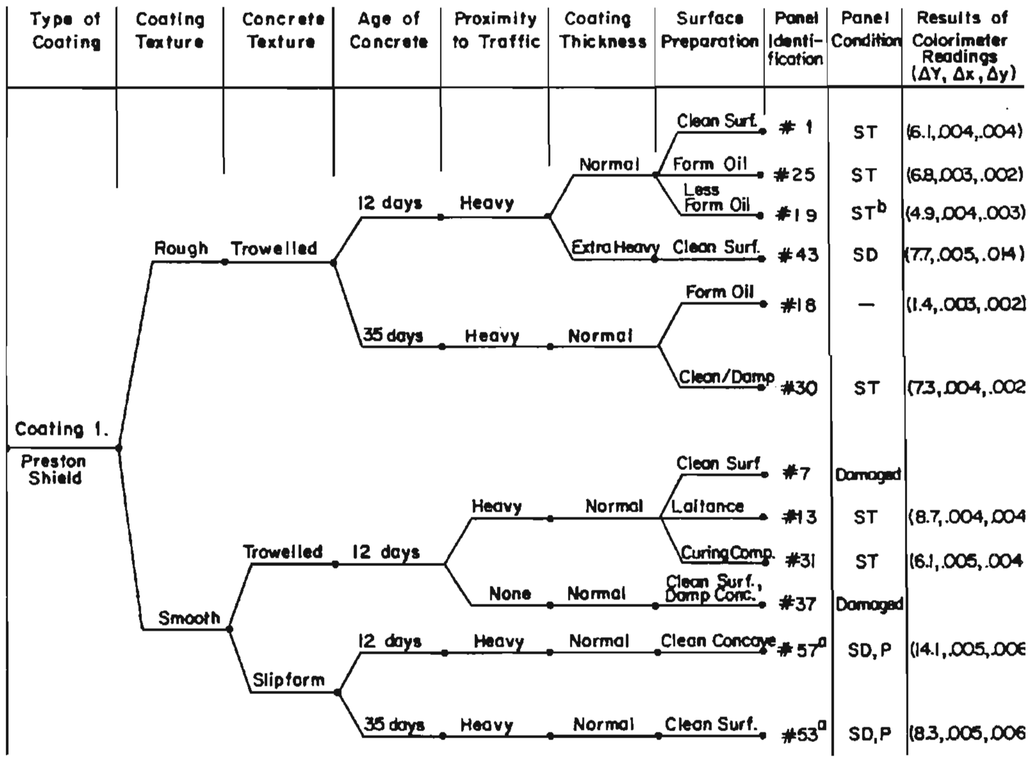


Fig 5.2. The results of the exposure test on test panels coated with Thorocoat® (legend for panel conditions given in section 5.2).

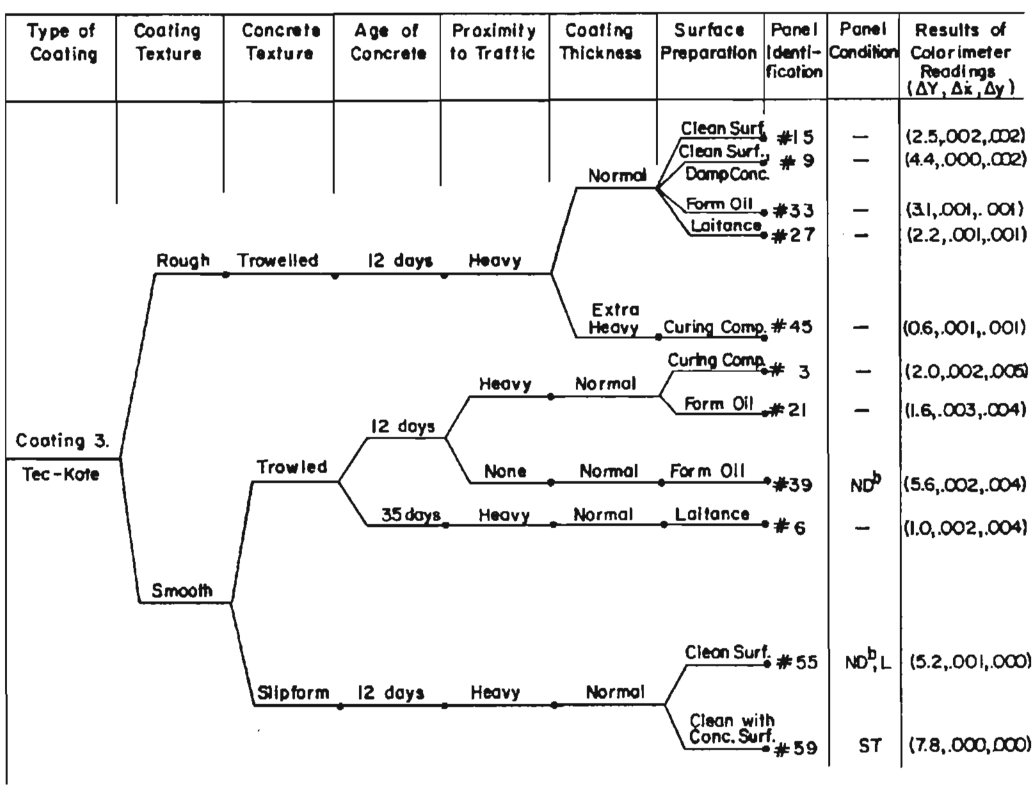


Fig 5.3. The results of the exposure test on test panels coated with Tec-Kote® (legend for panel conditions given in section 5.2).

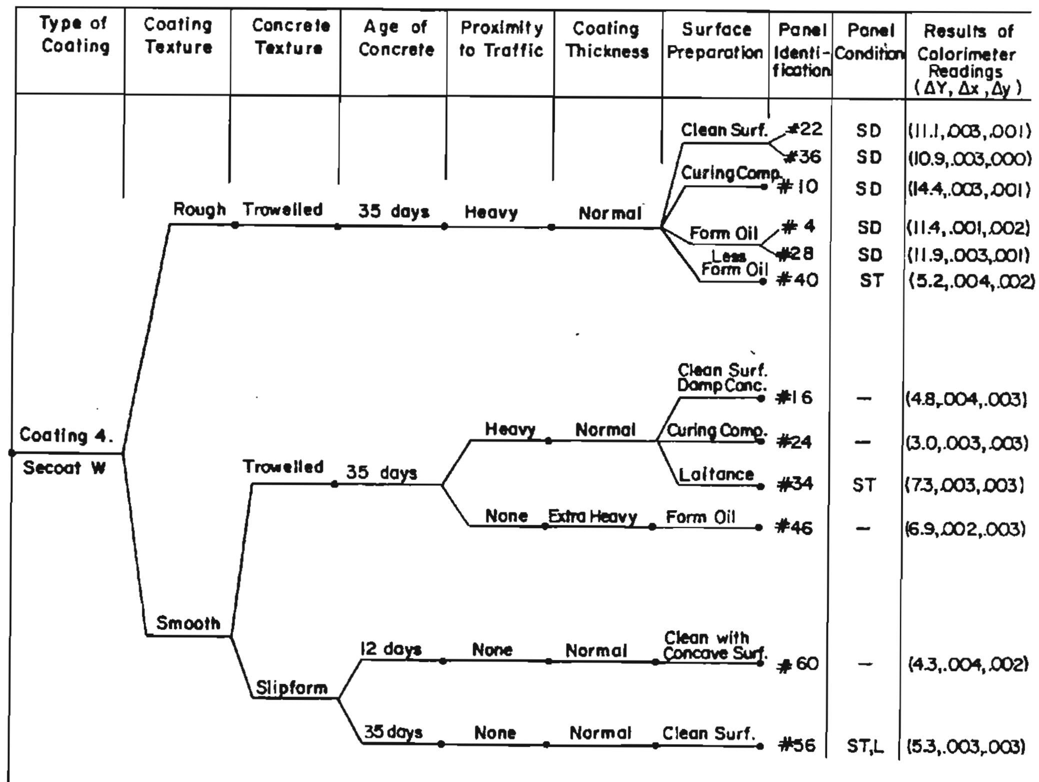


Fig 5.4. The results of the exposure test on test panels coated with Secoat W® (legend for panel conditions given in section 5.2).

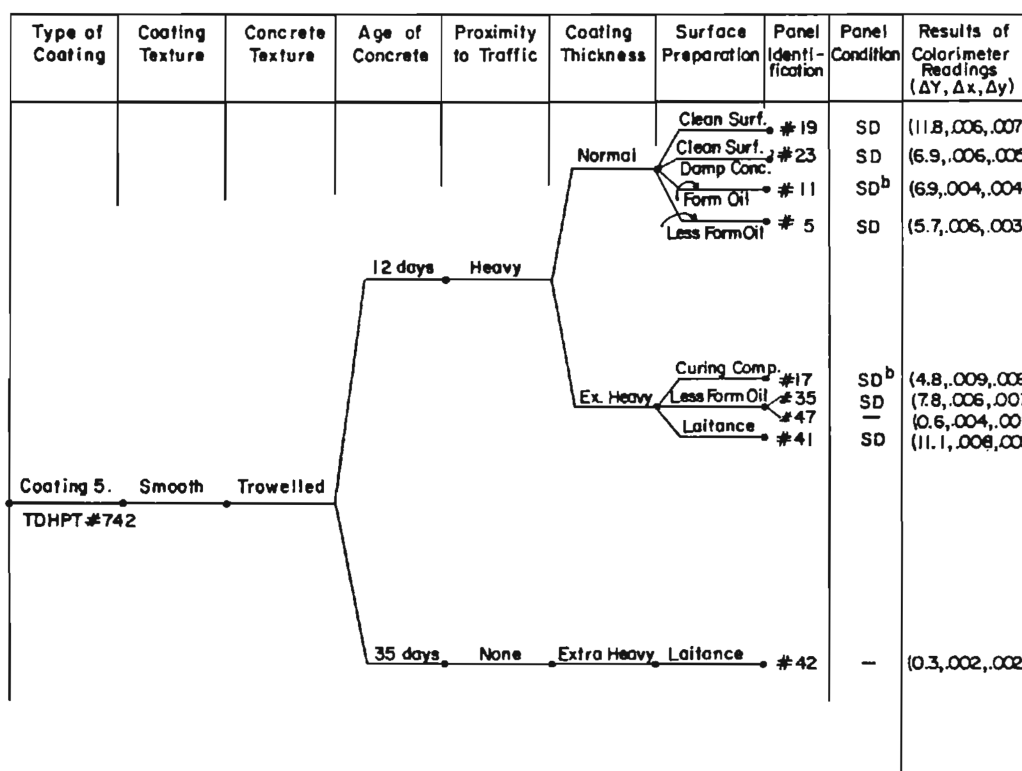


Fig 5.5. The results of the exposure test on test panels coated with TDHPT #742 (legend for panel conditions given in section 5.2).

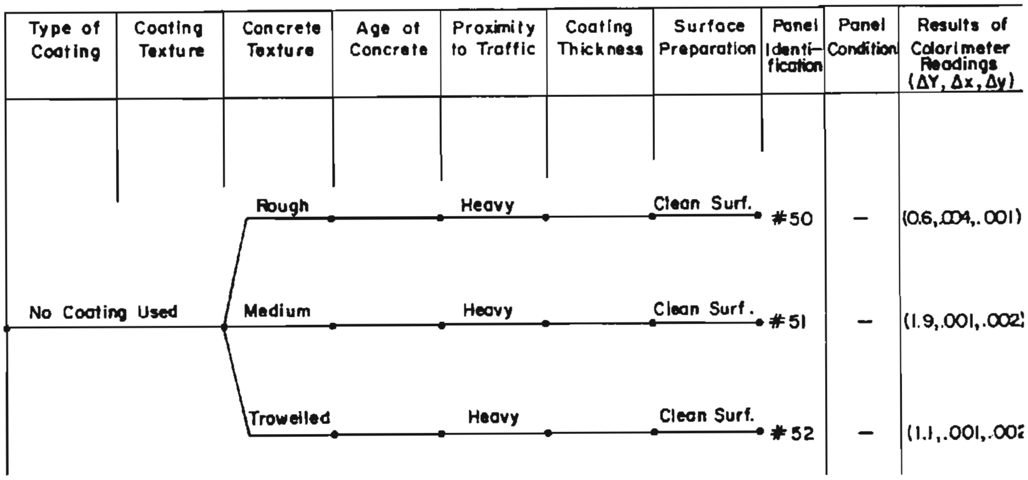


Fig 5.6. The results of the exposure test on the uncoated test panels.

SD : Significant darkening
ST : Showing trends towards darkening
P : Peeling of coating
L : Laitance or calcium hydroxide is forming beneath the coating film
ND : No sign of darkening according to the visual inspection
a : Panel was removed from traffic environment when peeling was observed
b : Discription of darkening was determined based on both colorimeter analysis and visual inspection
c : Calcium hydroxide is causing blistering in the coating

5.2.1 Type of Coating

As far as darkening of coatings is concerned, Tec-Kote® was found to show the least amount of discoloration. Next in order were Thorocoat®, Prestonshield, Secoat W®, and Highway Department #742. This is shown in Fig 5.7. However, it should mentioned that the coating type alone is not necessarily the only variable affecting the change in color. For example, a rough coating texture could possibly be factor contributing the most to the darkening of Secoat W®. Figure 5.8 shows photographs of darkened panels which had rough Secoat W® texture, and Fig 5.9 shows photographs of panels which had smooth Secoat W® texture and had no serious darkening problems.

It was interesting to observe that none of the three panels which had no coatings applied showed any significant indication of darkening, in spite of the fact that each of panels had a different concrete texture.

With respect to peeling of coatings, only the Prestonshield® coating experienced this type of distress. The peeling occurred in the slipformed panels after less than six months of exposure to the high traffic environment.

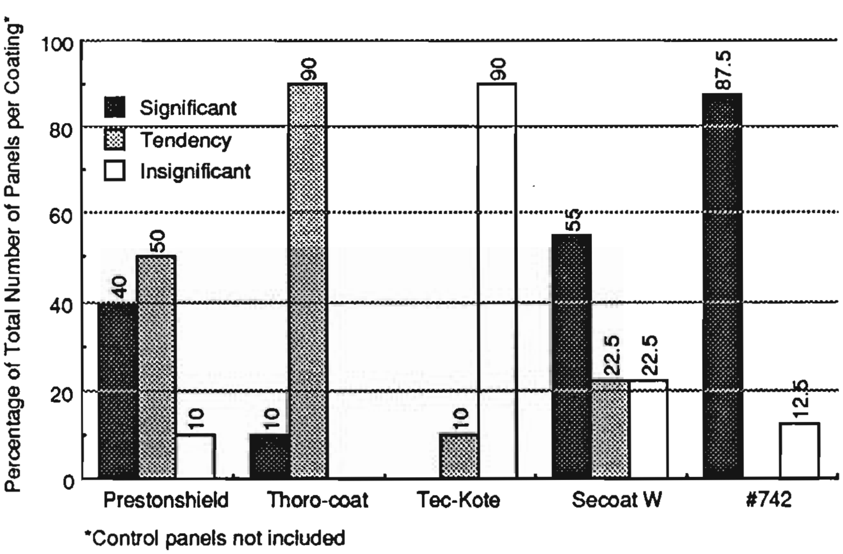


Fig 5.7 Darkening performance of the different coatings used.

5.2.2 Coating Texture

The finding from the field survey that a rough surface collected contaminants and exhaust emissions more easily than a smooth one is verified by an analysis of panels coated with Secoat W®. From Fig 5.4, all Secoat W® panels with a rough coating texture showed significant darkening. On the other hand, only 30 percent of those with a smooth coating texture, not including the control panels, showed trends towards darkening. However, this effect was not as pronounced in the other coatings. For instance, the effect of a rough coating texture was not observed in those panels coated with Prestonshield® or Thorocoat®. As can be seen in Figs

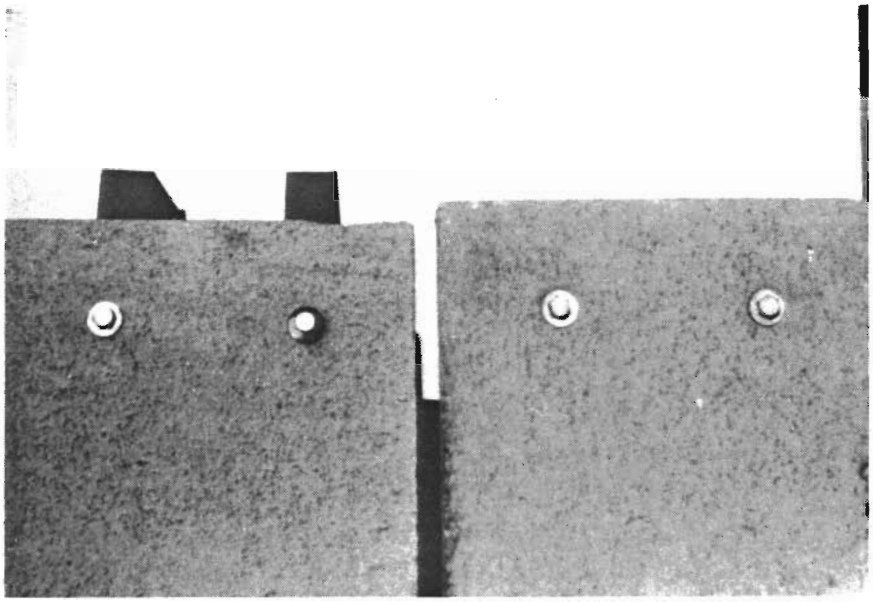


Fig 5.8. Paneis No. 4 and No. 22 which had a rough coating texture (Secoat W®) showing significant darkening.

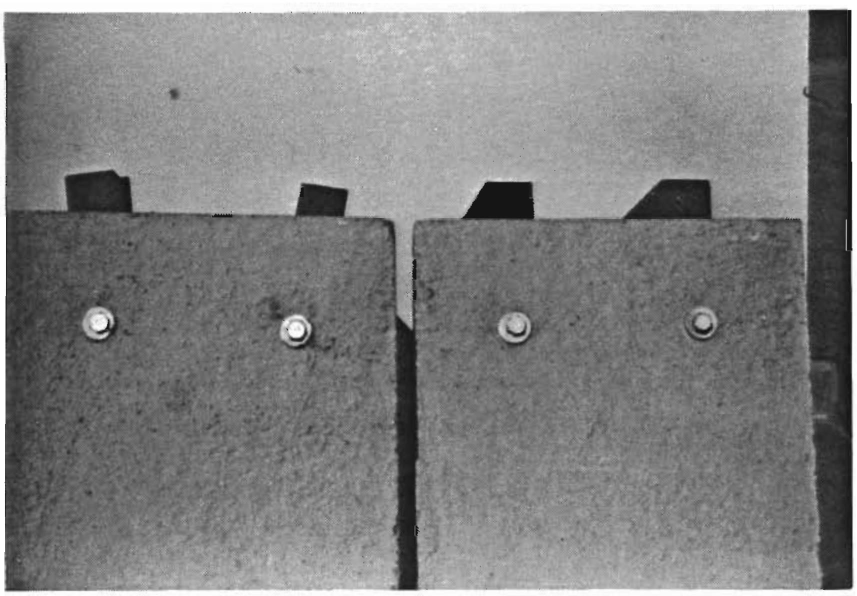


Fig 5.9. Paneis No. 24 and No. 16 which had a smooth coating (Secoat W®) showing no significant indication of darkening.

5.1 and 5.2, almost all panels in these groups have shown darkening.

In fact, the panels with a smooth coating texture seem to have experienced more darkening than those with a rough texture. However, the observed darkening in some of these smooth panels may be attributed to factors other than texture alone.

In the case of Tec-Kote® (Fig 5.3), it is difficult to draw conclusions on the effect of coating texture because practically no significant indication of darkening was observed in any of the panels, except for panel No. 59, which had a smooth coating texture and still showed a trend toward darkening. The darkening in this panel is believed to be due to the concave surface of the panel.

As shown in Fig 5.5, all panels coated with Highway Department #742 coating had smooth surfaces, but there was still significant darkening in 85 percent of the panels. This may be due to #742's being whiter than the other coatings and that it is in its nature to darken slightly.

5.2.3 Concrete Texture

As Fig 5.6 shows, none of the uncoated panels, which were constructed with various amounts of texture in the concrete surface, showed any sign of darkening. It seems that uncoated rough-textured concrete did not attract contaminants as readily as did smooth concrete with rough-textured coatings. This may be attributable to the different surface geometries produced by specific texturizing techniques. The concrete is texturized by brooming or brushing the wet surface to get a lightly grooved finish. The texture in the coating is produced by mixing relatively large particles of vermiculite into the liquid coating and spraying this mixture onto the concrete. The result of the impinging of the particles on the wet coating is small craters, which are incompletely filled with paint coated vermiculite. The edges of these craters trap dirt, which can discolor the surface coating over a period of time. The grooves, however, allow water to channel into and out of the deformation for a cleaner long-term finish.

The other possibility is that the initial darker color of the uncoated concrete may more closely approximate the color of the contaminant film which had collected on the surface.

It is not clear whether the trowelled concrete panels have experienced more darkening than the slipformed ones.

However, there were some unique findings related to slipform construction.

(1) Severe peeling was observed with both Prestonshield® coated panels, as shown in Figs 5.10 and 5.11.
(2) Blistering occurred in the Secoat W® coating of the slipformed panel No. 56, caused by the formation of laitance on the concrete surface beneath the coatings (Fig 5.12).

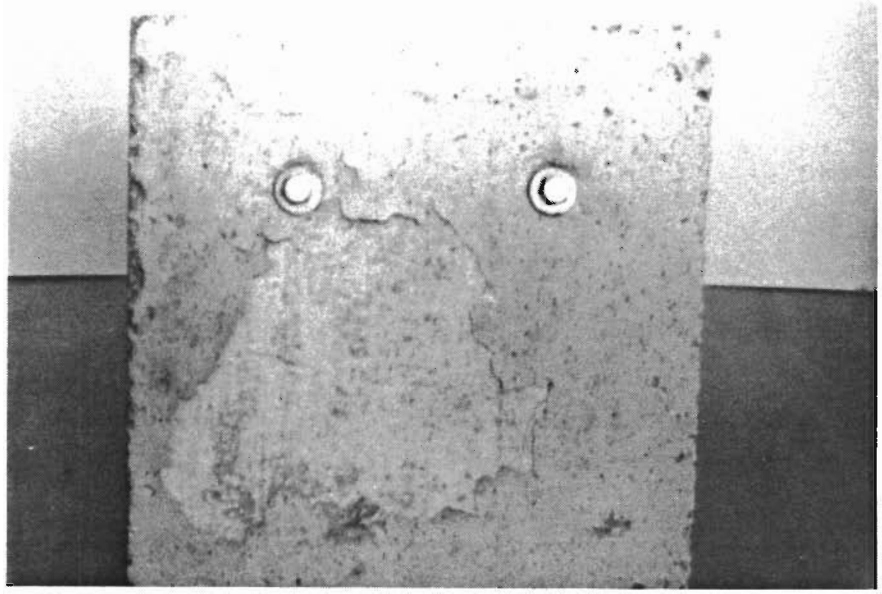


Fig 5.10 . Severe peeling of the Prestonshield® coating on a slipformed, flat surface.

5.2.4 Age of Concrete When Coated

It was thought that age of concrete when coated as related to moisture content in the concrete would be an important factor in explaining peeling problems with coatings. However, peeling was observed in only two panels, and each of these panels had a different concrete age when coating was applied. Therefore, this variable seems to have little effect on peeling.

5.2.5 Proximity to Traffic

In every coating group the panels placed in the area of high traffic volume experienced much more darkening that those placed several hundred feet from traffic. Thus, coating distress, darkening in particular, appears to be a function of traffic volume and the resulting emissions.

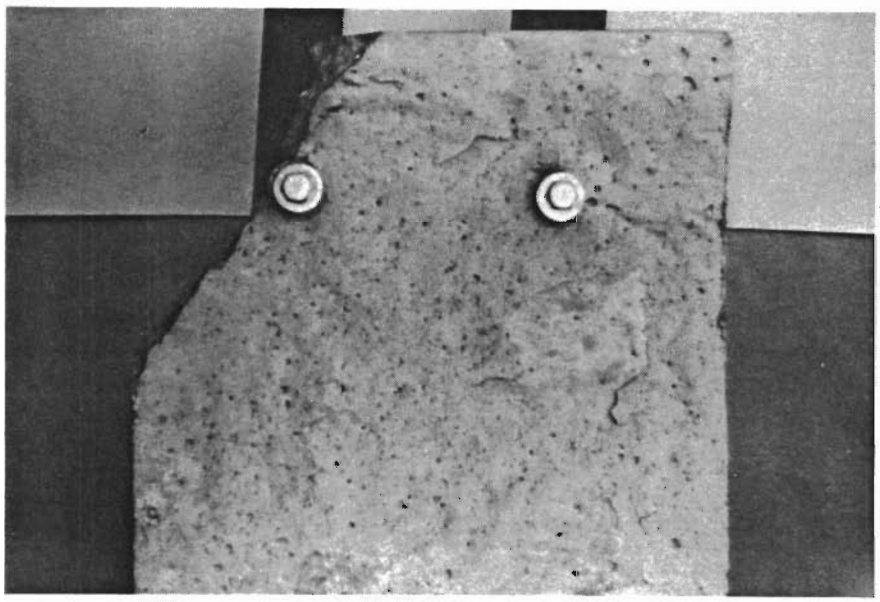


Fig 5.11. Severe peeling of the Prestonshield® coating on the slipformed, concave surface.

5.2.6 Thickness of Coating

Early opinions in the survey suggested that thickness of the coating contributed to the non-uniform darkening othsufaces (zebra stripes in San Antonio and Houston). Therefore, panels were made and coated to compare the thickness of coating to the degree of darkening.

Figure 5.1 indicates the darkening effect due to coating thickness is evident primarily in those panels coated with Prestonshield®. Panel No. 43, which had an extra-heavy thickness, showed significant darkening when compared with panels No. 1, No. 25, and No. 19, all of which had normal thicknesses of coating.

Also, panel No. 46 was the only one of the three Secoat W® coated panels to have the thicker coating, and it clearly exhibited the most darkening. These three panels were placed several hundred feet from traffic.

It would have been easier to make generalized inferences on the effects of coating thickness on darkening if the panels which were coated with the Highway Department #742 had exhibited a similar trend of thicker coated panels looking darker. They did not, and it seems plausible that, since the coating textures were all smooth in this group, thickness of the coating was not a significant factor. However, the rough textures in the Prestonshield® group may have contributed an additive effect on the thicker coating to produce a darker panel (No. 43).

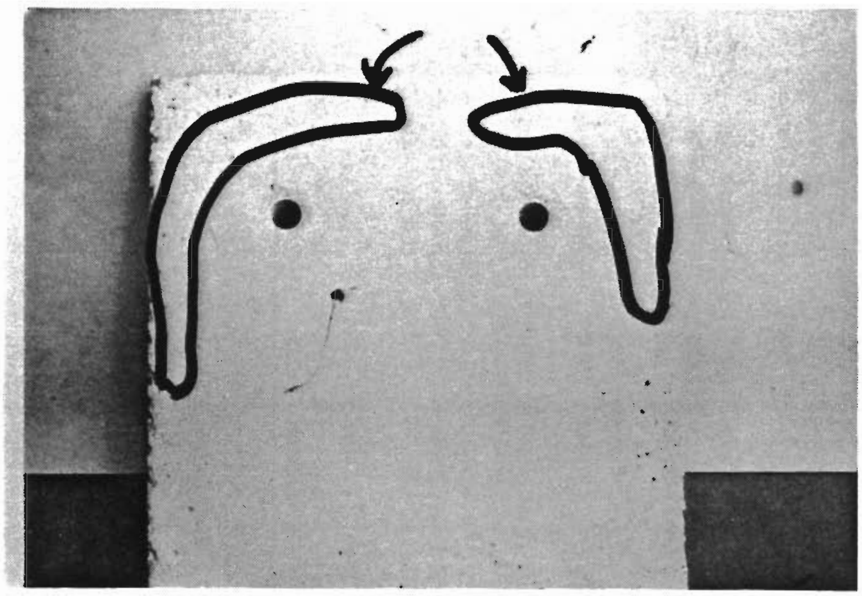


Fig 5.12 . Blistering of the Secoat W® coating on the slipformed panel No. 56.

It seems likely, then, that texture, which may be a function of coating thickness, may significantly contribute to darkening, and that darkening is not the result of thickness of coating alone.

5.2.7 Surface Preparation

The effect of surface conditions of the concrete was thought to be of utmost importance in peeling of coatings. It was expected that the panels that had clean surfaces when coatings were applied would not experience peeling and that those that had curing compound, form oil, or laitance on their surfaces and those where the concrete was soaked in water before the application of coatings would have a weakened bond between the coatings and the concrete resulting in coating peeling. None of this appears to be valid according to the findings shown in Figs. 5.1 through 5.5. As stated earlier, only two panels exhibited peeling and that was believed to be due to the combination of slipform construction and the application of Prestonshield® coating. It could be that the amount of curing compound or form oil applied in the tests was not enough to induce peeling.

Almost all panels which have a concave surface shape have exhibited more darkening than those which are in the same group, have the same combinations of test variables, and have flat surfaces. This is shown in Fig. 5.1 by comparing the colorimeter readings of panel No. 57 ($\Delta Y = 14.1$, $\Delta x = .005$, $\Delta y = .006$) with those of panel No. 53 ($\Delta Y = 8.3$, $\Delta x = .005$, $\Delta y = .006$), both coated with Prestonshield®. Even though both panels exhibited significant darkening, the ΔY of panel No. 57 by far exceeded that of panel No. 53. Similarly, panels No. 58 and No. 54, coated with Thorocoat®, exhibited the same phenomenon, with the concave surface in panel No. 58 showing significant darkening compared with a trend towards darkening exhibited by the flat surface of panel No. 54. The same is valid for panels No. 55 and No. 59, coated with Tec-Kote®. However, it should be noted that the colorimeter readings of the panels with concave surfaces might have been affected by measurement orientation problems caused by the surface geometry.

5.3 EFFECT OF SURFACE CLEANING

Several methods using various types of cleaners were used in attempts to wash off the surfaces. Several panels with different coating textures were selected for that washing. Only a portion of a panel surface was washed so that any change in color could be observed. The washing methods used were

(1) a Clorox® solution (one cup of Clorox® for each gallon of warm water) applied using a sponge),
(2) the same Clorox® solution applied using a sprayer,
(3) the same Clorox® solution applied using a soft brush,
(4) 409® cleaner applied using a sprayer,
(5) Electrasol® detergent applied using a sponge, and
(6) warm water under pressure using a standard laboratory outlet.

Table 5.3 shows the results of the washing analysis. The criteria described earlier in this chapter were used in determining the significance of change in color by washing. It was found that for both smooth and rough surfaces the application of the Clorox® solution using a sponge, the application of 409® by spraying, or the application of Electrasol® using a sponge produced a significant change in color towards whitening. The application of the Clorox® solution using a soft brush was found to produce a slight to medium change in color whereas washing with sprayed Clorox® or moderate pressure water was found to be the least effective.

Figure 5.13 shows the results of washing a rough texture (panel No. 22) with Clorox® using a sponge. Figure 5.14 shows the results of washing a panel (No. 10) that has the same coating and texture with 409® by spraying. Figure 5.15 shows the results of washing a panel (No. 36) from the same group with water under pressure. The first two indicate a significant change in color, while the other one does not show any visible change.

It is interesting to note that although the colorimeter analysis showed no significant indication of darkening in the

TABLE 5.3 CHANGE OF PANEL CONDITIONS AFTER WASHING

Type Of Coating	Texture of Coating	Panels Washed	Washing Method	Before-Wash Readings			After-Wash Readings			Difference			Change In Color Towards Whitening
				Y	x	y	Y	x	y	ΔY	Δx	Δy	
Preston	Rough	43	Clorox-sponge	34.8	0.327	0.335	40.4	0.325	0.334	5.6	0.002	0.001	Medium change
	Smooth	31	409-spray	39.5	0.327	0.335	50.8	0.323	0.333	11.3	0.004	0.002	Significant change
Thorocoat	Rough	12	409-spray	22.7	0.329	0.338	25.3	0.327	0.336	2.6	0.002	0.002	Slight change
	Rough	20	Clorox-spray	23.7	0.329	0.339	25.2	0.329	0.338	1.5	0	0.001	Slight change
	Smooth	54	Clorox-soft brush	25.1	0.329	0.338	27.8	0.327	0.337	2.7	0.002	0.001	Slight change
Tec-Kote	Rough	15	409-spray	35.3	0.324	0.335	44.3	0.323	0.333	9	0.001	0.002	Significant change
	Rough	9	Clorox-soft brush	36.1	0.324	0.335	40.4	0.323	0.333	4.3	0.001	0.002	Medium change
Secoat W	Rough	22	Clorox-sponge	21.3	0.328	0.336	32.9	0.327	0.337	11.6	0.001	0.001	Significant change
	Rough	28	Clorox-spray	23.5	0.327	0.335	25.4	0.328	0.337	1.9	0.001	0.002	Slight change
	Rough	10	409-spray	25.2	0.326	0.334	35.2	0.327	0.337	10	0.001	0.003	Significant change
	Rough	4	Electrasol-sponge	25.0	0.328	0.336	36.2	0.32	0.33	11.2	0.008	0.006	Significant change
	Rough	36	warm water spray	25.3	0.327	0.335	26.7	0.327	0.336	1.4	0	0.001	Slight change
#742	Smooth	35	Clorox-soft brush	35.3	0.316	0.328	38.5	0.313	0.324	3.2	0.003	0.004	Slight change
	Smooth	29	409-spray	29.9	0.318	0.329	43.7	0.312	0.323	13.8	0.006	0.006	Significant change
	Smooth	23	warm water spray	35.3	0.317	0.327	37.2	0.316	0.326	1.9	0.001	0.001	Slight change

Tec-Kote® panel No. 15 between initial and final readings (D = 2.5), a significant change was recorded (D = 9), after the panel was cleaned. This would seem to indicate that significant discoloration of the coating did occur but that the change was masked by the fact that the initial color of Tec-Kote® coating was very close to the color of the collecting film of dirt and emissions. On the other hand, the Clorox® treatment actually bleached the coating surface.

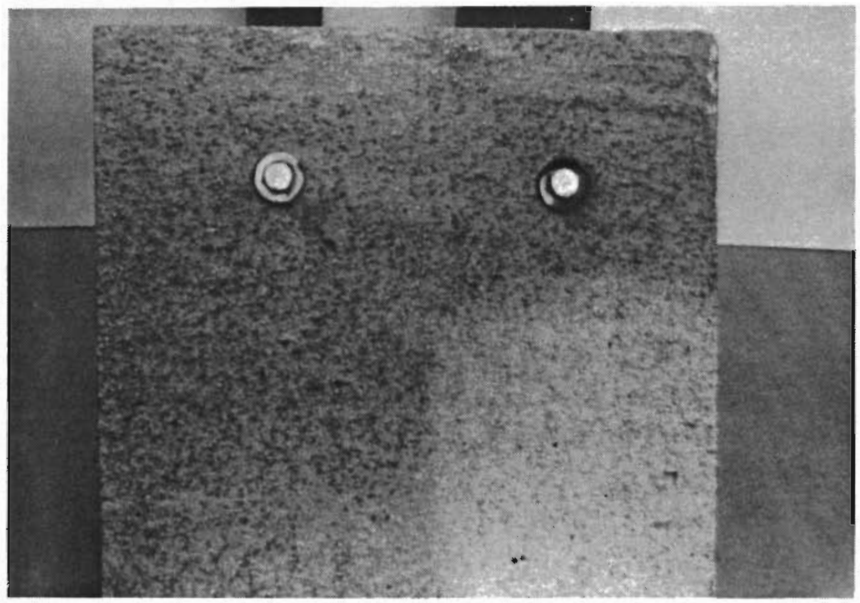


Fig 5.13. Rough-textured panel (No. 22) washed with Clorox® using a sponge ($\Delta Y = 11.6$).

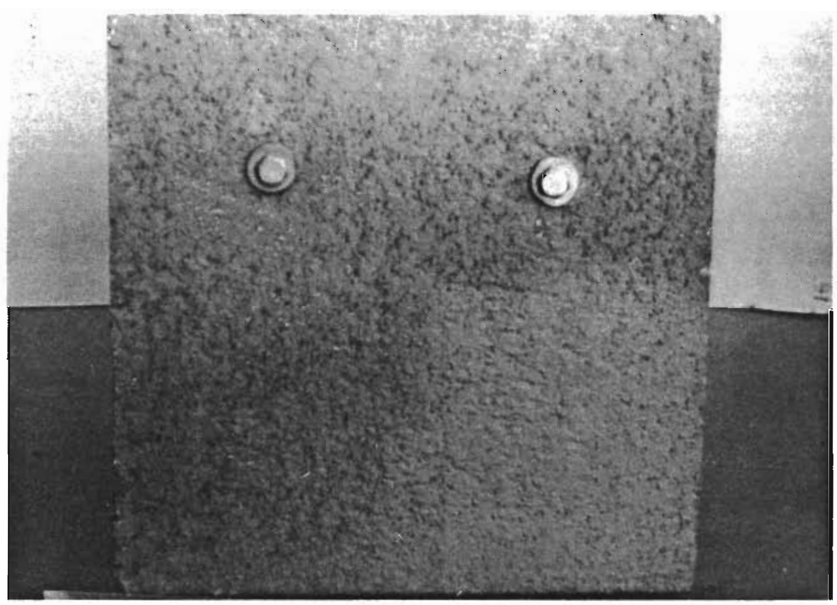


Fig 5.14. Rough-textured panel (No. 10) washed with 409® by spraying ($\Delta Y = 10.0$).

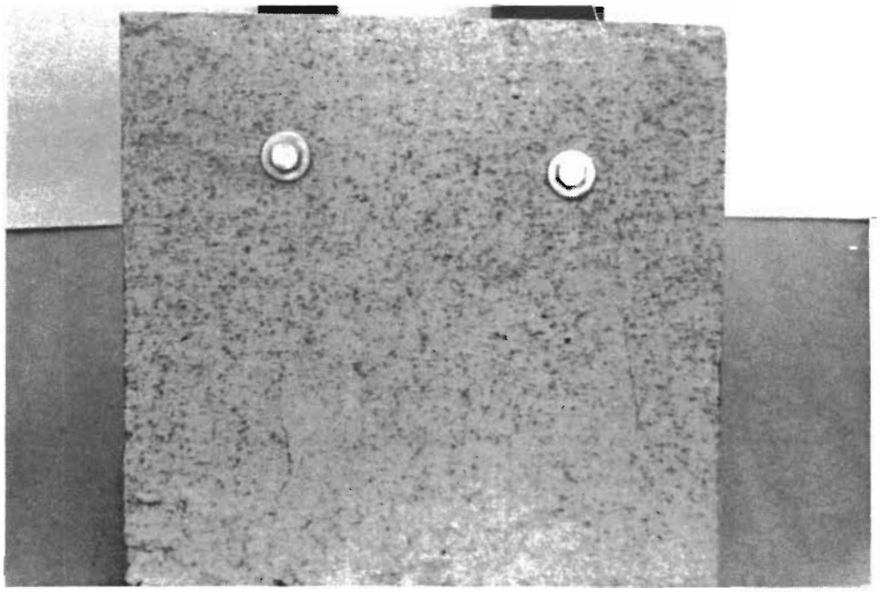


Fig 5.15. Rough-textured panel (No. 36) washed with water under pressure ($\Delta Y = 1.4$).

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions were drawn from the study, based on the results of the surveys and the test panel program:

1. Darkening of concrete structures was found to be due to the accumulation of dust and vehicle emissions on the surface.
2. From the findings of the survey of Texas Districts, there was a strong indication that rough coating surfaces experienced more darkening than smooth ones. The survey of other states (Tennessee) supported the correlation between rough coating surfaces and darkening. The analysis of test panel data tended to support this finding to a limited extent; however, the rough texture effect was not conclusive in all coating types used.
3. In the test panel study, the panels without coatings which had different degrees of concrete texture experienced no darkening. This may be attributable to the geometries of the grooving finish, which seems to attract fewer contaminants, as well as to the fact that those panels had low initial and final 'Y'. These values indicate that the panels started with a relatively dark initial color, which matched the color of the contaminant film collecting on the surface.
4. According to the survey of Texas Districts, thickness of coating was a factor contributing to peeling and darkening of coatings. The analysis of panel data indicated that the darkening of a thick coating is more likely to occur when the coating texture is rough.
5. Peeling of coatings was observed on some concrete structures where curing compound was used. In fact, District 4 personnel had indications that the greater the rate of curing compound used, the more severe the peeling. The analysis of test panel data revealed that the use of a curing compound did not result in bond deterioration and, thus, did not initiate peeling; however, the amount of curing compound used may not have been sufficient to induce peeling. Similarly, soaking concrete in water for 24 hours or the use of form oil did not cause peeling of the test panel coatings.
6. Peeling was found to be much more prevalent on slipformed median barriers than on any other type of structure. SDHPT personnel and a painting contractor confirmed this finding. Even water-blasting the surface prior to coating does not insure that peeling would not occur. In the test panel study, two of the eight simulated slipformed panels, panels No. 53 and 57, with smooth Prestonshield® coating textures exhibited severe peeling; two other panels, panel No. 54 with a smooth Thorocoat® coating texture and panel No. 55 with a smooth Tec-Kote® coating texture, showed blistering caused by the formation of laitance on the surface, which may eventually result in peeling.
7. Test panels with a concave surface exhibited more darkening than those with a flat surface shape.
8. The age of concrete when coated was not found to be significant in causing peeling.
9. Darkening of coatings was found to be a function of proximity to traffic and traffic volume.
10. Some coatings were found to have experienced more darkening than others (Tec-Kote®, according to the surveys, and Highway Department #742, according to the analysis of test panel data).
11. Darkened material could usually be removed by the application of soap and water. On the test panels, the application of a Clorox® solution using a sponge, of 409® cleaner by spraying, or of diluted Electrasol® detergent with a sponge produced a significant change in color towards whitening.

6.2 RECOMMENDATIONS

1. Coatings on concrete structures should be eliminated where possible, particularly on slipformed median barriers. As an alternative, sandblasting or water-blasting could be used to provide a more uniform appearance.
2. If coatings are used, the following procedures should be employed
   a. Surfaces should undergo sand-injected or detergent-injected water blasting to remove laitance, curing compound, and other contaminants (high pressure sand blasting may be an acceptable alternative). If detergent-injected water blasting is used, it should be followed by thorough flushing with fresh water.
   b. Concrete may need to be surface-dried prior to application of the coating, particularly when alkyd-based or acrylic-based coatings are used.
   c. Texture on the concrete surface and in the coating material should be eliminated, or at least reduced significantly, to minimize the collection of emissions and other contaminants.
   d. The field surveys indicate that the current specification requiring a coverage of 45 plus or minus 5 square feet per gallon should be maintained to eliminate excessive or inadequate coating thicknesses.

e. #742®, which is currently approved for use in painting steel structures, should be considered as an acceptable coating due to its rapid drying. In the panel tests, #742®, even with a smooth surface, darkened more from its initial reading than the other darker coatings with a smooth surface. However with a darker variation of #742®, the advantages of the material make it a good candidate for an acceptable coating.

f. For aesthetic purposes, the cleaning of coated structures may become part of the normal maintenance program.

3. Darkened surfaces can be cleaned by one of several methods:
   a. Large areas should be cleaned by sand-injected or detergent-injected waterblasting.
   b. Small areas such as column bases, or areas where waterblasting is undesirable, should be cleaned by
      1. spraying on 409® cleaner,
      2. applying a solution of Clorox® with a sponge, or
      3. applying a solution of Electrosol® detergent with a sponge.