DEVELOPMENT OF AN ADHESION TEST FOR TRAFFIC BUTTONS, MARKERS AND JIGGLE BARS

D. L. O'CONNOR
SUPERVISING CHEMICAL ENGINEER

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TEXAS HIGHWAY DEPARTMENT

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By

D. L. O'Connor
Supervising Chemical Engineer

Materials and Tests Division
Texas Highway Department

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FOREWORD

In the past, Texas Highway Department specifications for traffic buttons, markers and jiggle bars have not contained a provision specifying the degree of adhesion to be developed between the marker and epoxy adhesive. District 18 experienced a very high loss rate with plastic buttons placed in 1968. Tests performed on these buttons indicated that the degree of adhesion obtained was considerably lower than that obtained with ceramic markers. Examination of samples of reflective markers supplied recently revealed that some batches had a loosely bonded layer of filler material on the bottoms which might interfere with good adhesion. In order to insure that markers obtained by the Highway Department will have a clean, sound bonding surface, it was decided that an adhesion test should be developed and a minimum adhesion requirement specified.

This report presents the work performed in developing a test procedure and setting a minimum adhesion requirement.

ABSTRACT

A procedure was developed to determine the degree of adhesion obtainable to traffic markers using a standard epoxy adhesive. Bond tests to several different types of markers were performed at 0, 77 and 140 F and also after freezing and thawing. A bond strength of 500 psi at 77 F was selected as the minimum for satisfactory performance.

SUMMARY

In order to insure that traffic markers obtained by the Texas Highway Department will have a clean, sound bonding surfaces, it was decided that an adhesion test should be developed and a minimum adhesion requirement specified. Such a procedure was developed using a standard epoxy adhesive. Bond tests were performed at 0, 77 and 140 F and also after freezing and thawing with several different types of markers. A bond strength of 500 psi at 77 F was selected as the minimum for satisfactory performance. No requirements were established at 0 and 140 Feor after freezing and thawing. However, the adhesion tests performed at 140 F revealed that the fill material of the reflective markers softens considerably at this temperature. This extreme softening could result in failure of the marker itself when subjected to high pavement temperatures and heavy traffic.

IMPLEMENTATION

The test procedure developed in this project has been designated as Test Method Tex-611-J, Adhesion Test for Traffic Buttons, Markers and Jiggle Bars, and placed in the Manual of Testing Procedures. A bond strength of 500 psi was set as the minimum for compliance with the adhesion requirement.

I. SUBJECT

Development of an Adhesion Test for Traffic Buttons, Markers and Jiggle Bars.

II. PURPOSE

The purpose of this project was to develop a procedure to evaluate the adhesion obtainable on traffic buttons, markers and jiggle bars using a standard epoxy adhesive and to arrive at a minimum bond strength requirement.

III.e CONCLUSIONSe

As a result of this work, a test procedure was developed for determininge the adhesion to various traffic markers using a standard epoxy adhesive.e It was designated as Test Method Tex-611-J, Adhesion Test for Traffice Buttons, Markers and Jiggle Bars, and placed in the Manual of Testinge Procedures. Based on the performance of several different types of markers,e a bond strength of 500 psi was selected as the minimum for satisfactorye service. Tests performed on the various markers currently used by thee Texas Highway Department indicate that some markers currently in stocke will not comply with the minimum 500 psi adhesion requirement. However,e in tests performed on these markers after a small amount of surface preparation, strengths well in excess of the 500 psi requirement were obtained.e

Tests were performed on composite specimens after freezing and thawing and at 0 and 140 F, but it was decided that no adhesion requirements under these conditions would be recommended at this time. However, the adhesion tests performed at 140 F point out a characteristic of the reflective markers, particularly Brand A, which could adversely affect their performance at the upper limits of roadway temperature. The reflective markers soften and evidence very low adhesive strengths at 140 F. The extreme softening of the fill material could result in failure of the marker itself under heavy traffic.

IV.e MATERIALSe

The materials used in this investigation consisted of the traffic markerse and the raw materials used to prepare two epoxy adhesives.e

Traffic Markerse

A list of the markers selected for evaluation is presented in Table I.e All of the markers were obtained from the Seguin warehouse withe the exception of the Brand B reflective markers which were purchased from Shepler Equipment Company, Houston.

TABLE I

Traffic Markers Selected for Evaluation

Marker	As-Received Condition
Ceramic buttons, white	Buttons were covered with a light coat of dust which had collected during warehouse storage. The bottoms of some of the buttons were soiled with dirt or grime.
Ceramic buttons, yellow	Buttons were clean - no loose material or dust on bottoms.
Plastic buttons, white	Condition same as white ceramic buttons.
Pyrex Glass, white	Buttons were covered with a light coat of dust.
Ceramic Jiggle Bars, white	Condition same as yellow ceramic buttons.
Markers, Type IA, Brand A	Markers were clean, but bottoms were covered with loosely bonded filler material.
Markers, Type IR, Brand A	Condition same as Type IA, Brand A.
Markers, Type IR, Brand B	Condition same as Type IA, Brand A, except amount of loose material present on bottoms was not as great.

Epoxy Adhesives

The epoxy adhesives used in this work were prepared from the basic raw materials listed in Table II. The composition of the adhesives is shown in Table III.

TABLE II

Identification of Raw Materials Used in Epoxy Adhesives

Raw Material	Manufacturer
Epi-Rez 509 Epoxy Resin	Celanese Resins
Epon 815 Epoxy Resin	Shell Chemical Company
Butyl Glycidyl Ether	Celanese Resins
N-Aminoethyl Piperazine, technical grade	Jefferson Chemical Company
Nonyl Phenol	Jefferson Chemical Company
LP-3 Polysulfide	Thiokol Chemical Company
DMP-30 Amine	Rohm and Haas Chemical Company
Asbestine X Talc	International Talc, Inc.
Wollastonite, Grade P-4	Interpace Pigments
R-900 Titanium Dioxide	DuPont Chemical Company
Excelsior Carbon Black	Columbian Carbon
RG-144 Asbestos	Union Carbide

TABLE III

Composition of Epoxy Adhesives

Adhesive I	Adhesive II
Resin Components	
100 pbw* Epon 815	97 pbw Epi-Rez 509
	3 pbw Butyl Glycidyl Ether
37.64 pbw Asbestine Xe	50 pbw Wollastonite P-4
7.31 pbw Titanium Dioxidee	5 pbw Titanium Dioxide
2.67 pbw RG-144	3.4 pbw RG-144e
Hardener Components	
52 pbw Nonyl Phenol	46 pbw Nonyl Phenol
23.16 pbw N-Aminoethyl Piperazinee	20 pbw Aminoethyl Piperazine
77.37 pbw Asbestine Xe	15 pbw LP-3
1.00 pbw RG-144e	1.4 pbw DMP-30e
0.22 pbw Carbon Black	72 pbw Wollastonite P-4

*The abbreviation pbw is used for parts by weight.

V. DEVELOPMENT OF TEST PROCEDUREe

Previous to this work, a limited evaluation of adhesion between variouse markers and epoxy adhesives had been performed using a modification ofe ASTM D 1062 (Cleavage Strength of Metal to Metal Adhesives). A cleavagee block was coated with adhesive and bonded to the marker bottom. Aftere the adhesive had cured, a cleavage grip was attached to the compositee specimen and the apparatus placed in a tensile testing machine. A steele plate with a hole cut in the center was used to support the marker in thee cross head of the machine and the specimen was loaded to failure in tension.e

This procedure worked fairly well. It was thought that more consistent results could be obtained using a larger bonding area and applying the load at the mid point of the area rather than on one edge as is the case with the cleavage test. Steel specimens were machined from two inch diameter steel rods. The finished specimens consisted of a two inch diameter steel disk approximately 5/8 inch thick to which was attached a shoulder with a hole drilled in the center to which a standard cleavage grip could be attached. This disk would give a bonded area of 3.d4 square inches. To prepare an adhesion test specimen, the steel disk was bonded to the center of the marker bottom with an epoxy adhesive. After the adhesive had cured, a 1/4 inch thick steel plate with a 2-1/4 inch diameter hole cut in the center was slipped over the disk and used to support the composite specimen in the crosshead of the testing machine. The apparatus prior to assembly is shown in Figure 1. The assembled apparatus ready for placement in the testing machine is shown in Figure 2.

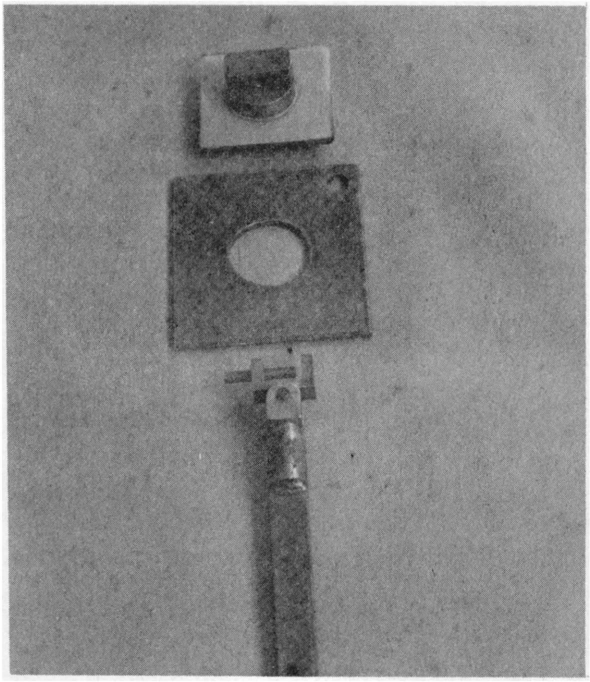

Figure 1

Test Apparatus Prior to Assembly

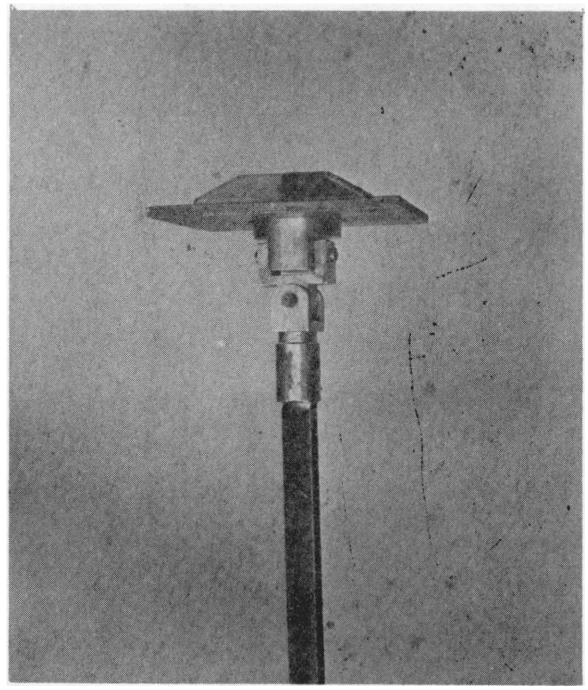

Figure 2

Assembled Apparatus Ready for Placement in Testing Machine

Based on previous experience, there are several factors which could have considerable influence on the results obtained from an adhesion test. These include the procedure followed in preparing the test specimen, the type of epoxy adhesive used and the temperature of the adhesive and test specimen. In developing a test procedure, the following items would have to be decided:

1. The exact procedure to be followed in preparing the test specimen.
2. The type of epoxy adhesive to be used.
3. The temperature of application and use.
4. The length of cure given the epoxy adhesive prior to testing the specimens.

5. The temperature at which the test is to be performed.

The adhesive used should comply with Texas Highway Department Specification Item 575 for marker adhesives and ideally should have characteristics as close as possible to the adhesives most often used on Highway Department projects. So that the characteristics of the adhesive would not vary a great deal, it was decided that it would be best to work with adhesives formulated from the basic raw materials. Adhesives I and II were prepared as indicated under Materials. These adhesives were tested for compliance with Item 575 and the results are presented in Table III. Adhesive I complied with the requirements for Type III-M material while adhesive II complied with all requirements for Type III and III-M materials.

Two procedures for preparing test specimens were tried. A description of the procedures follows:

Procedure No. 1:

The bonding surface of the steel disks was blasted to white metal with No. 60 Garnet Blasting Abrasive, supplied by Clemtex Company, Houston, using a 1/4 inch diameter gun nozzle and a gun pressure of 50 to 75 psi. After blasting, the surfaces to be bonded were washed with methyl ethyl ketone.

Approximately 50 grams of the adhesive were weighed into a three ounce metal ointment can. The two components were then mixed together for two minutes using a small square-ended stainless steel spatula. Two to three grams of the mixed adhesive were then applied to the center

TABLE IV

Results of Tests on Adhesives I and II

Test	Results Obtained	
	Adhesive I	Adhesive II
Mixing Ratios	1 to 1 by volume	1 to 1 by volume
	1.00 resin to 1.04 hardener by wt.	1.08 resin to 1.00 hardener by wt.
Viscosities @ 77±1 F,		
Resin Component	1336	1364
Hardener Component	770	742
Pot life at 77 F, Minutes	9	10
Set Time at 77 F, Hours	2-3/4	2-1/4
Tensile Shear Strength, psi, avg.	3098	3079
Cleavage Strength, psi, avg.	1233	1267
Impact Strength, ft-lbs., avg.	8.6	9.0
Water absorption, % by wt., avg.	0.24	0.14
Wet Strength, psi, avg.	450	405

of the steel disk. The disk was then inverted, centered over the bottom of a marker, pressed down and rotated slightly. Sufficient pressure was applied to cause extrusion of the adhesive around the edge of the disk.

Procedure No. 2:

Preparation of the steel disks and mixing of the adhesive was the same as in Procedure 1. Approximately two grams of the mixed adhesive were applied to both the steel disk and the center of the marker bottom. The adhesive was then spread uniformly over the surface of the steel disk and over an approximately 2-1/2 inch diameter area on the marker bottom. The disk was then inverted and pressed down firmly against the marker bottom.

The initial temperature of all materials and the room temperature was 77 ± 2 F for both procedures.

Based on previous experience, the epoxy adhesives should develop adequate strengths after 24 hours cure at 77 ± 2 F. It was decided that a minimum cure time of two days would be given all specimens prior to test.

In order to compare the two specimen preparation procedures, ten white ceramic and ten Brand A Type IR markers were selected at random and test specimens prepared. The ceramic button bottoms were wiped lightly with a clean dry cloth to remove any loose dirt or dust. The Type IR markers were turned up on edge and tapped against a table top to remove any loose filler particles which would come off easily. Five markers of each type were used to prepare specimens with Adhesive I following Procedures 1 and 2. After the adhesive had cured for two days at 77 ± 2 F, the specimens were loaded in tension until failure occurred. The rate of loading was approximately 2000 pounds per minute. The results obtained with Adhesive I are presented in Table V and the results with Adhesive II are presented in Table VI.

In the case of the ceramic markers, the failure was predominantly cracking or breaking of the button regardless of the procedure or adhesive used. There was some loss of adhesion to the steel disk or between the button and the adhesive, but this was only on the order of 5 to 10% of the bonded area. The only exception to this was specimen 1, using Adhesive I and Procedure 2, on which the failure was 100% loss of adhesion between the button and the adhesive. A typical failure is shown in Figure 3.

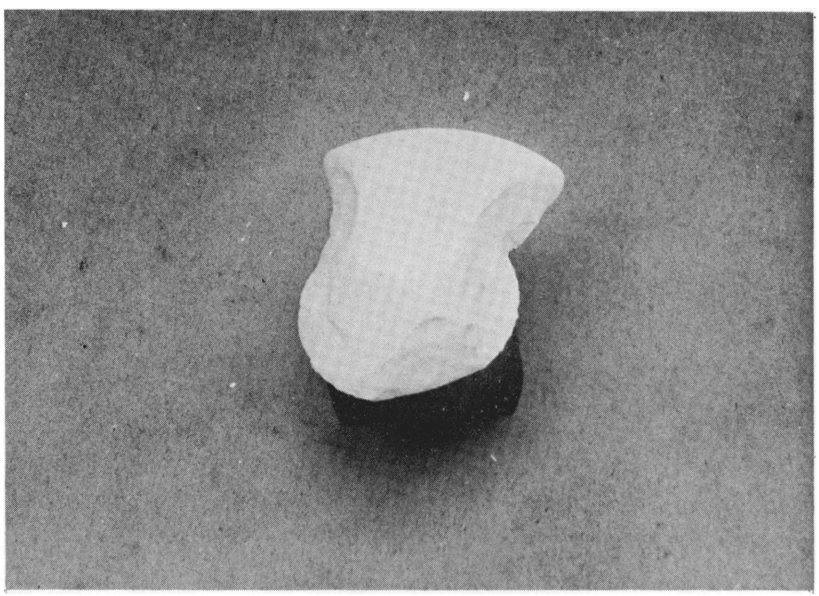

Figure 3

Typical Ceramic Button Failure

TABLE V

Bond to Markers Obtained Using Adhesive I and Different Specimen Preparation Procedures.

	White Ceramic		Type IR Brand A	
	Procedure 1	Procedure 2	Procedure 1	Procedure 2
Specimen	Stress, Psi	Stress, Psi	Stress, Psi	Stress, Psi
1	939	207*	627	653
2	1051	1236	548	255*
3	1229	1162	624	691
4	860	1051	621	455
5	1092	1099	583	678
Average	1035	1137	601	619

TABLE VI

Bond to Markers Obtained Using Adhesive II and Different Specimen Preparation Procedures.

	White Ceramic		Type IR Brand A	
	Procedure 1	Procedure 2	Procedure 1	Procedure 2
Specimen	Stress, Psi	Stress, Psi	Stress, Psi	Stress, Psi
1	1006	1019	599	233*
2	879	930	659	525
3	596	812	573	691
4	777	1115	398	525
5	560	1121	573	611
Average	764	999	560	588

*Because of the large difference between the values obtained for these individual specimens and the other specimens in the test group, these values are not included in the averages shown.

Although the lowest strengths were obtained with Adhesive 2 and Procedure 1, no real significance could be attached to this because the failures occurred in the buttons themselves.

The Brand A markers utilize an epoxy-glass bead mixture as the filler for the body of the marker. The type of failure experienced with the Type IR, Brand A markers was about 75% separation of a thin layer of glass beads from the body of the marker. About 25% of the failures occurred deeper (1/32 inch or more) into the body of the marker. A typical failure is shown in Figure 4. There was no significant difference in the bond strengths obtained with the two different adhesives and preparation procedures.

After reviewing the test results it was decided that Adhesive II would be used as the standard epoxy adhesive for additional tests. This decision was based upon the fact that it complied with all requirements for both Type III and III-M adhesive under Item 575 and from the standpoint of composition was a better representation of the adhesives currently being supplied for Highway use.

Procedure 1 was selected for preparation of specimens because it is more typical of the procedure followed in field placement of markers.

VI.e TEST RESULTS AND DISCUSSIONe

The bond test was performed on the remaining marker samples with teste conditions as follows:e

Adhesive - No. II

Procedure - No. 1

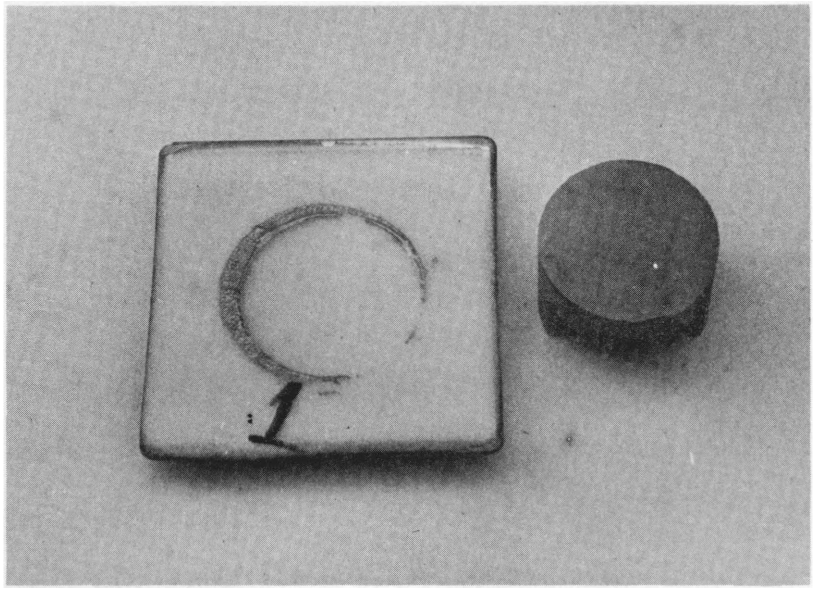

Figure 4

Typical Brand A Marker Failure at 77 F

Ambient temperature and temperature of materials at time of specimen preparation and cure - 77± 2 F.

Cure time - 48 hours

Rate of loading - 2000±200 pounds per minute.

Since the pyrex glass and plastic buttons had a coat of dust on them accumulated in warehouse storage, the bottoms were wiped lightly with a clean dry cloth. Specimens were prepared with the yellow ceramic buttons and the ceramic jiggle bars exactly as received. The Type IA Brand A and Type IR Brand B markers were tapped to remove completely loose filler material on the bottom of the markers.

The results obtained for the various markers are presented in Table VII.

TABLE VII

Bond Strength for Various Markers

Stress, psi

Specimen No.	Pyrex Glass Buttons	Plastic Buttons	Yellow Ceramic Buttons	Ceramic Jiggle Bars*	Type IA, Brand A	Type IR, Brand B
1	739	334	1602	1481	242	586
2	599	354	920	968	175	669
3	621	175	879	1704	395	631
4	669	255	748	1799	121	586
5	557	430	1481	1895	236	561
6	605	280	1201		245	-**
7	669	366	1051		312	532
8	430	341	971		191	592
9	637	318	1255		318	646
10	557	264	1401		255	535
Average	608	312	1151	1569	249	593

*Ten specimens were prepared with the ceramic jiggle bars but the remaining five were not tested because the high total load was bending the pin connecting the cleavage grip and the steel disk.

**Specimen 6 failed at a comparatively low load - an accurate reading was not obtained.

The mode of failure for the yellow ceramic buttons and the jiggle bars was the same as the white ceramic buttons. Because of the high loads obtained with the jiggle bars, the test grip was modified prior to further testing. The wall thickness of the grip and the diameter of the connecting pins was increased to 5/16th inch. The holes in the shoulders of the steel disks were drilled out to accomodate the larger pin. In the case of the pyrex glass buttons, the failure averaged about 75% in the button itself (cracking and breaking) and about 25% loss of adhesion between the button and the epoxy. The bottoms of the Brand B markers are coated with an approximately 30 mesh size chat-type material. The surface texture is rougher than that of the Brand A markers.

An examination of the bonding surface of the steel disks after failure revealed that about 70% of the surface was covered with chat pulled away from the marker. Because of the roughness of the marker bottom, the remaining 30% had never obtained a bond to any part of the marker surface. A typical specimen after testing is shown in Figure 5.

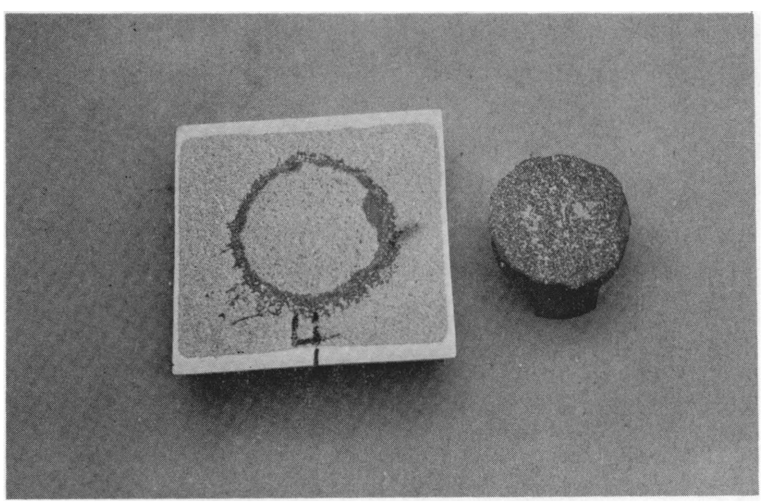

Figure 5

Typical Brand B Marker Failure at 77 F

The failure of the Brand A Type IA markers was of the same type as the Brand A Type IR markers. The main difference was the considerably lower load at failure.

In the case of the plastic buttons, the type of failure was 100% loss of adhesion between the button and the epoxy.

The main difficulty encountered in the field with loss of adhesion between markers and adhesive was with the plastic markers. Since the bond developed with the Brand A Type IA markers was of approximately the same magnitude, it would be expected that problems might be encountered with these markers. As previously mentioned the Brand A markers have a considerable amount of loosely bonded glass beads present on the bottoms which does not give a good sound surface for bonding. As a matter of interest, several methods of cleaning the loose material from these markers was tried and test specimens prepared with these markers. The methods of treating the bottom surface of the markers were as follows:

1.e Light sandblasting with No. 60 Garnet Grit, using a 1/4 inche diameter nozzle and a gun pressure of 50 to 75 psi.e
2.e Brushing using a steel bristle hand brush.e
3.e Sanding by hand with a medium grit sandpaper.e

The sandblast treatment was also tried on the bottoms of the plastic buttons. Because of the toughness of the plastic buttons, a light brush blast did not have much effect, so they were subjected to heavier blasting than the Brand A Type IA markers. Bond test results obtained on specimens prepared with the treated markers are presented in Table VIII.

TABLE VIII

Bond Strength to Markers with Specially Prepared Bottoms

Specimen No.	Stress, psi Type IA Sandblasted	Type IA Wirebrushed	Type IA Sanded	Plastic Buttons Sandblasted
1	889	341	631	895
2	997	338	567	757
3	1051	389	682	713
4	860	309	548	599
5	975	411	653	752
Average	954	358	616	743

All three methods of removing the loosely bonded layer from the Brand A Type IA markers resulted in some improvement. The light sandblasting provided the best bond. The bond obtained approached the strength of the marker filler material. An example of the type of failure obtained is shown in Figure 6. Sandblasting the bottoms of the plastic buttons also resulted in bond strengths approaching the strength of the button itself. Failure was approximately 90 percent in the button and 10 percent loss of adhesion between the button and the adhesive.

These tests showed that it is possible to obtain an extremely good bond to both the Brand A markers and the plastic buttons provided the bonding surface is clean and sound.

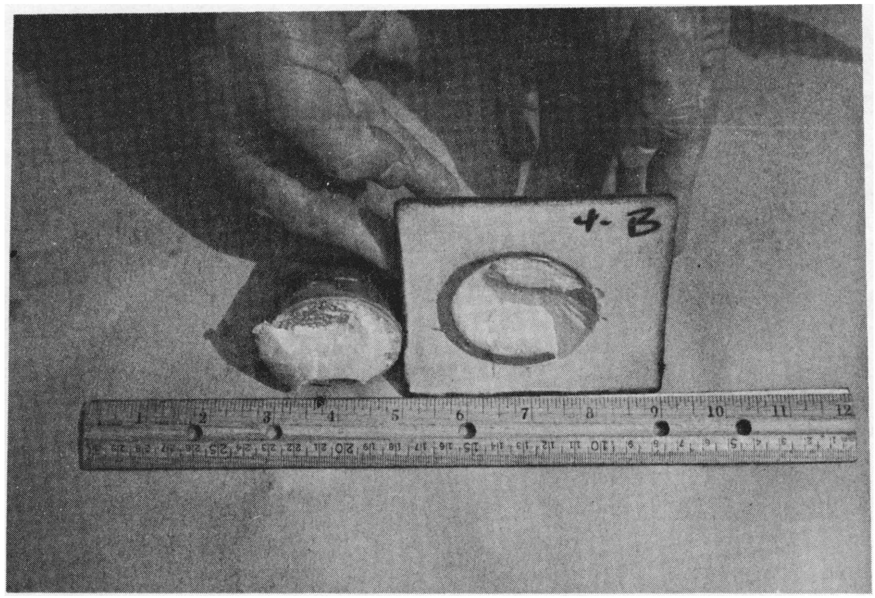

Figure 6

Brand A Marker Failure at 77 F After
Light Sandblasting of Bottom

In order to evaluate the effect of freezing and thawing on the bond strength, additional specimens were prepared with the white ceramic, pyrex glass and plastic buttons, the Brand A Type IA and Brand B Type IR markers. After curing, the specimens were subjected to 10 cycles of freezing and thawing. One cycle consisted of five hours in a freezer maintained at 0 F followed by three hours in the air at 75-80 F. After the freezing and thawing was completed, the specimens were subjected to tensile loading until failure occurred. The results are presented in Table IX.

The bond to the reflective markers and plastic buttons was not affected by the freezing and thawing. The strength of the bond to the ceramic

TABLE IX

Bond Strength to Markers After Freezing and Thawing

	Stress, psi				
Specimen No.	White Ceramic	Pyrex Glass	Plastic	Brand A Type IA	Brand B Type IR
1	487	239	408	146	570
2	525	245	274	373	513
3	621	274	280	322	573
4	844	239	277	449	--*
5	729	436	261	207	484
Average	641	287	300	299	535

*This specimen was not tested because of difficulty in attaching it toe cleavage grip.e

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markers was lower than obtained in previous tests. Failure was approximately 50 percent in the markers and 50 percent loss of adhesion between the button and the epoxy. All of the glass buttons, with the exception of specimen 1, developed visible cracks adjacent to the steel disks as a result of the freezing and thawing. This was the reason for the low strengths obtained with the glass buttons. Since there is an appreciable difference between the thermal coefficients of expansion and contraction for glass and steel or ceramic material and steel, cracking of the glass buttons and lowering of bond strength to ceramic buttons might not occur in actual use. Several of the glass buttons were bonded to concrete mortar panels and after the adhesive had cured, the composite specimens were subjected to freezing and thawing along with unbonded buttons. After a total of 20 freeze-thaw cycles, no cracking of the buttons or loosening of the bond was noted.

Additional bond tests were performed at low and high temperatures with the white ceramic and plastic buttons and the Brand A Type IA and Brand B Type IR markers. The Brand A Type IR markers were also included in the high temperature test. Specimens were prepared, cured 48 hours, and then brought to 0 F in a freezer.

The specimens were then removed from the freezer individually and loaded to failure. The results obtained are presented in Table X.

TABLE X

Bond Strength to Markers - Loading Performed with Specimens Initially at 0 F.

	Stress, psi			
Specimen No.	White Ceramic	Plastic	Brand A Type IA	Brand B Type IR
1	724	398	80	322
2	669	271	80	315
3	589e	366	134	385
4	748e	303	96	446
5	693e	334	99	430
Average	685e	334	98	380

The load at failure for the ceramic buttons was lower than that obtained in room temperature tests. However, the mode of failure was predominantly in the button, so the lower strengths could not be attributed to a poorer bond. The bond strength and type of failure for the plastic buttons was essentially the same as obtained in room temperature tests. The type of failure with the reflective markers was the same as experienced in room temperature tests, but the strengths were considerably lower. It is possible that this was due to thermal stresses in the composite specimens which weakened the bond at low temperature.

Specimens were then prepared, cured for 48 hours and brought to 140 F in an oven. The specimens were removed individually from the oven and immediately loaded to failure. The results obtained are presented in Table XI.

The strength of the bond to the ceramic and plastic buttons at 140 F was equivalent to that at 77 F. The mode of failure for the ceramic buttons was approximately 60% fracturing of the button and 40% cohesive failure of the adhesive. The type of failure for the plastic button was essentially 100% loss of adhesion between the button and adhesive. In the case of the reflective markers, the fill material softens considerably at 140 F. For the Brand A markers the failures occurred completely in the fill material approximately 1/32 to 1/16th inch into the body of the marker. Figure 7 shows a typical failure for these markers. In the case of the Brand B markers, failure consisted mainly of separation between the chat on the bottom of the markers and the body of the marker. A typical failure is shown in Figure 8.

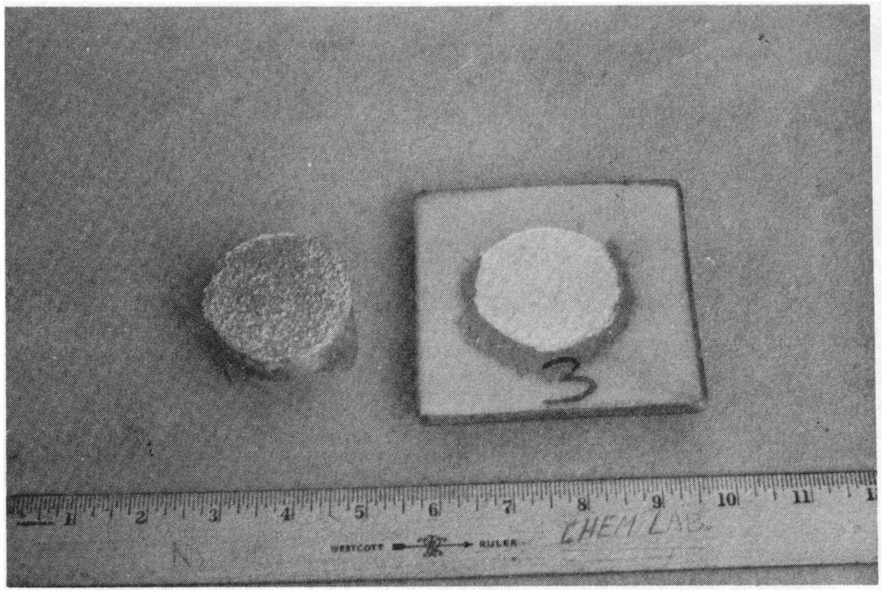

Figure 7

Typical Brand A Marker Failure at 140 F

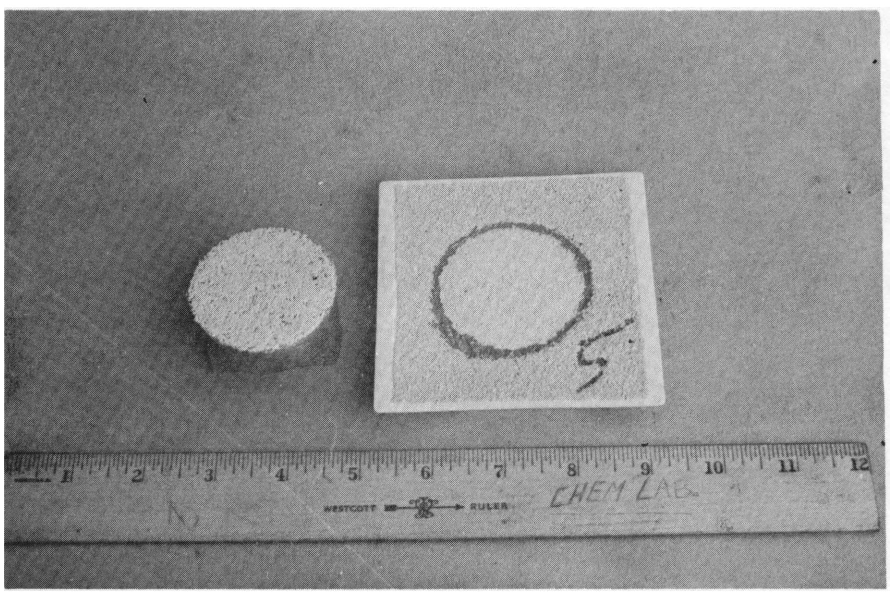

Figure 8

Typical Brand B Marker Failure at 140 F

TABLE XI

Bond Strength to Markers, Loading Performed with Specimens Initially at 140 F.

Specimen No.	Stress, psi White Ceramic	Plastic	Brand A Type IA	Brand A Type IR	Brand B Type IR
1	1003	420	108	96	153
2	780	478	102	86	150
3	971	223	99	86	140
4	971	239	111	92	140
5	1401	490	102	86	134
Average	1025	370	104	89	143

After reviewing the results of all the tests performed, it was decided that a bond strength requirement determined at 77± 2 F should be included in all marker specifications. As previously mentioned, the most severe problem encountered in the field with loss of adhesion between markers and the adhesive occurred with the plastic buttons. Since they evidenced a bond strength on the order of 300 psi in this test, the minimum requirement should be greater than this. A minimum requirement of 500 psi bond strength for all types of buttons and markers was decided upon with the test conditions to be as presented on pages 14 and 15. Test Method Tex-611-J, Adhesion Test for Traffic Buttons, Markers and Jiggle Bars, was prepared for inclusion in the Texas Highway Department Manual of Testing Procedures.

It was decided that no requirement on adhesion after freezing and thawing or at low or elevated temperatures would be recommended at this time. However, the adhesion tests performed at 140 F pointed out a characteristic which could obviously affect performance of the reflective markers. It is quite possible for markers, especially those placed on asphaltic concrete, to reach a temperature of 140 F during the summer. The extreme softening of the fill material could result in failure of the marker itself under heavy traffic.