STATE OF CALIFORNIA

DEPARTMENT OF TRANSPORTATION
DIVISION OF NEW TECHNOLOGY,
MATERIALS AND RESEARCH

NEW MATERIALS AND TECHNIQUES FOR THE REHABILITATION OF PORTLAND CEMENT CONCRETE

FINAL REPORT # FHWA/CA/TL-85/16

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16. Abstract

Details of test installations of overlays less than one inch thick are given. Various types of concrete repair materials are discussed along with test procedures developed to evaluate the products. New developments in repair techniques are also described. Specifications for rapid set patching materials and organic polymer concrete overlays are included in the appendices of the final report. Test results of numerous PCC patching materials are listed.

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English Unit	Multiply By	To Get Metric Equivalent
Length	inches (in) or (")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft) or (')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litre (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lb)	4.448	newtons (N)
	kips (1000 lb)	4448	newtons (N)
Thermal Energy	British thermal unit (Btu)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (in-lb)	.1130	newton-metres (Nm)
	foot-pounds (ft-lb)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (°F)	$\frac{°F - 32}{1.8} = °C$	degrees celsius (°C)
Concentration	parts per million (ppm)	1	milligrams per kilogram (mg/kg)

Preface

We wish to thank the many contributors to this study, both government and private, for without their cooperation, we could not have accomplished this work. Contributions from the many firms that produce these materials cannot be overemphasized; many gave technical advice, others assisted in supplying materials over the several years of this study. These firms submitted materials for testing prior to and after the study had officially taken its present form. Several of the products tested have since been removed from the market because the companies marketing them felt those materials did not meet their objectives, given the Caltrans evaluation. This was not an intended goal of Caltrans, but we do admire the courage and objectivity demonstrated by these firms. Several products have been modified to meet the new test parameters. This has significantly improved the industry's general performance. Not only are far better materials available, but this study has provided an objective baseline of performance for all suppliers and users. We hope this report will be utilized toward that end.

This research evolved as presented here without following a well-developed outline. Thus, we specifically wish to commend the Sacramento office personnel of the FHWA. Without the flexibility, confidence, and support of Mr. Cannon and Mr. Schmitt, this project could not have succeeded.

We also extend a special thanks to those directly connected with this research program over the several years. Among these are the Transportation Laboratory machine shop staff for their infinite patience in building and rebuilding jigs and fixtures needed "yesterday"; the support of management through several changes in command and, specifically, Mr. Bill Neal, principal researcher (now retired) who generally directed this study and Mr. Jim Woodstrom, since promoted to management. Conducting many of the tests personally were Messrs. Henry Jerzak, Paul Krauss and Dave Wong all presently at the Laboratory.

Test areas "on the street" and engineering services were provided singularly or in combination by Messrs. Paul Jurach and Carl Stewart, Structures Research and Implementation, Mr. Raymond Hackett, Structures Maintenance, Mr. Edward Dunn, District 2 Structures Construction, Mr. Myron Jacobs, District 3 Structures Construction, and Mrs. Irene Itamura, Transportation Design, District 3. We would also like to thank the Laboratory Clerical Pool for their continued support and assistance.

L.R.F.
Sacramento
October 1985

The numerous requests for this publication were so great, as to deplete the original printing. It is not customary to print additional copies, but the demand continues and a second edition was decided upon. The second edition corrects errors found after the first edition was published. These involve poor picture quality, printing errors in figures, plates and pages. Also, Appendix II "specifications" have been revised to reflect more appropriate material values and test methods. The California Tentative Test Methods have been formalized to California Test 551 and 552. I hope this publication will be of value to those who must make decisions with little research and experience to draw from.

L.R.F.
Sacramento
November 1990

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INTRODUCTION

This research project has expanded considerably since its origination in 1978. The original objectives were 1) to investigate new materials and techniques for use in the repair and rehabilitation of concrete pavements, 2) to evaluate the performance of experimental field installations involving selected materials and/or procedures, 3) to develop alternative methods of rehabilitation based on cost-effectiveness and various constraints which might be imposed, 4) to prepare guidelines for the implementation of new procedures, and 5) to disseminate information to project engineers using various forms of communication, including workshops.

It quickly became clear that test procedures to accurately evaluate the multitude of new materials were not available. At the beginning of this research, reliable patching materials for repair of portland cement concrete (PCC) were not locally available. There was also a need for a durable, fast setting, thin bonded overlay material for use in chain wear areas or in areas with lane closure time restrictions.

Thus, this report contains several proposed test methods for rapid set patching materials and a performance specification for rapid set patching materials. Discussions of the properties of several types of inorganic and organic patching materials and the test results for nearly fifty patching materials are included.

Considerable research into the development of thin bonded polymer overlays was performed under this project. The formulation of polyester-styrene and high molecular weight methacrylate (HMWM) polymer overlay systems is discussed. Specifications for both systems are included. A discussion of California's experience with several other types of thin bonded polymer overlays is also included.

Organic polymers have great potential for the rehabilitation of transportation structures. The rapid setting time and superior physical characteristics of the polymer materials will be increasingly demanded as traffic loadings increase and the available time for repairs decreases.

Updates on current research and the needs for future research are addressed.

SUMMARY AND CONCLUSIONS

Several test methods for evaluating rapid set patching materials were developed. New test methods to determine workability, abrasion resistance, and bonding strength to saturated surface dry (SSD) and dry PCC are included. The current Caltrans performance specification for rapid set patching materials was developed based on the new test evaluation series. These specifications are restrictive, but defensible. Although several proprietary patching materials comply with these new specifications, most do not.

Organic polymer overlays have been placed and are performing well. Both types developed under this study (polyester-styrene and HMWM) have several advantages. They are highly abrasion resistant and are impermeable to water and road salts. They may be placed 3/8" to 1" thick, reducing dead load and clearance problems. Modifications to barrier rails and signing can therefore be avoided. Also, both concretes are rapid setting and, thus, well suited to night work when lane closure time is limited. Polyester-styrene polymer concrete overlays, in particular, appear to be a cost-effective rehabilitation technique. The addition of a silane coupler to the resin has significantly increased the resin bonding strength to aggregate and PCC. High molecular weight methacrylate concrete has several advantages such as low resin viscosity (decreases the resin demand) and superior bonding strength (less extensive surface preparation required). Physical properties have been determined and specifications for each of these overlay systems are presented.

Proper surface preparation is essential for nearly all thin bonded polymer overlays. Steel shot blasting appears to be superior to sandblasting or chipping for the thin-bonded overlays tested. High Molecular Weight Methacrylate resin as a prime coat may reduce the need for surface preparation under certain circumstances.

A system to effectively seal cracks in PCC bridge decks that utilizes high molecular weight methacrylate (HMWM) resin has been developed. This technology is especially useful for areas where epoxy injection is not possible due to the cracks being too small. Flood-treatment using HMWM has

successfully mended cracked bridge decks in the field. Specifications have been developed and are included.

Polyester-styrene and HMWM concrete have been used effectively for repairing bridge expansion headers for asphalt concrete overlays.

Polyester-styrene resin seal coats to increase skid resistance have been successfully placed. This technology offers an alternative rehabilitation technique with potential for extensive use in the future. However, construction problems presently exist and additional research is necessary.

Test results indicate that, compared to PCC, modified high alumina rapid set materials provide less, and magnesium phosphate rapid set materials provide more corrosion protection for embedded reinforcing steel.

A test method utilizing a nuclear density gauge in the backscatter mode for determination of the consolidation of bonded polymer concrete overlays has been developed and is incorporated in current contract specifications.

Very rapid setting urethane resins have potential for emergency spall repairs on PCC and asphalt concrete (AC) pavements. Repairs may be returned to traffic within minutes and repairs may be made when water is present. However, further research is required.

Two-component silicone foam has been used to subseal PCC pavement slabs to mitigate faulting. Laboratory and initial field test results are very promising and further research is being conducted.

IMPLEMENTATION

A significant increase in the quality of available rapid set patching materials has resulted from this research. This trend should continue as more manufacturers improve their products for use in California. As product quality increases, repairs will become more permanent and reduce the need to redo previous repairs.

The implementation of a performance specification for rapid set patching material no longer limits the types of materials that may be used. Past specifications often limited the acceptable materials to those with either a magnesium phosphate or a high alumina cement base. This new specification should encourage the development of other types of materials and result in a cost savings to the owner. This will also allow the organic polymers to compete directly with the inorganic materials, thus opening future technologies for highway rehabilitation.

The flood treatment of bridge decks with HMWM has almost become a routine maintenance procedure to extend the life of structures before major rehabilitation is required. An example of this is a savings of some $215,000 or over 95% of the estimated repair cost on the Rio Vista Lift Span Bridge as described in this report.

Polyester-styrene and HMWM concrete overlays have been very successful and are presently being used for rehabilitating bridges. They have several benefits over conventional rehabilitation techniques. Their use is predicted to increase in the future as more structures require rehabilitation and the technology becomes more familiar.

Polyester-styrene resin seals provide a rehabilitation strategy to increase skid resistance. There is presently a significant demand for this technology and the results of the preliminary field trials look very promising. This technology will be specified in several future rehabilitation projects.

Polyester-styrene concrete overlays are being seriously considered for the rehabilitation of pavements subject to chain wear. Several test sections have

been installed on Interstate 80 near Donner Summit. In 1985, work began on a contract to overlay ten lane miles with polyester-styrene concrete on Interstate 80 near Whitmore.

This study has also indicated future research that is needed to continue to improve the design and rehabilitation of highway structures.

RAPID SET PATCHING MATERIALS

An objective of this research was to evaluate many types of patching materials that could be used for repairing spalls in structures and pavements. This evaluation included a large number of proprietary compounds plus generic formulations by the researchers. Many materials underwent an evolutionary improvement during this evaluation as their strengths and weaknesses were discovered. The classifying of materials in order of overall performance resulted in the reformulation and improvement of several of these products while this research was underway. Thus, the rank of the products changed frequently during this testing and evaluation procedure. What was considered good performance at the beginning of this work is now considered as very poor and generally unacceptable. Test methods and performance specifications were developed for rapid set patching materials and are included in the appendix. Nearly 50 different patching materials have been evaluated using these test methods.

Laboratory test methods are also included in the appendix. For specification compliance, compressive strength tests are performed at 3 and 24 hours. Also, 24-hour tests for flexural strength, bond to SSD and dry PCC, sensitivity to moisture, and abrasion loss are specified. Tests for initial drying shrinkage and thermal properties are currently being developed and may soon be incorporated into the specification. If the material will be used near reinforcing steel or prestressing steel, the specification limits the amount of free sulfates and chlorides. A specification for freeze-thaw resistance is included when applicable. Caltrans' current "Specification for Packaged Materials to be Used for Rapid Set Repairs of Portland Cement Concrete Pavement and Structures" is included in the appendix.

Patching materials may be classified as organic materials or inorganic materials. As discussed in this report, organic materials are considered to be various types of polymers. Organic materials that have been evaluated are from the following families: epoxy, polyester, acrylic and urethane. The majority of the inorganic patching materials can be classified in four categories: portland cement based materials, gypsum based materials, magnesium phosphate, and modified high alumina cements. An overview of the typical properties and characteristics of each type of material will be presented. Test results of various patching materials tested are presented in the appendix.

A. Inorganic Patching Materials

Inorganic materials have several advantages. They are relatively inexpensive, safe, easy to use, and readily available. They have been used extensively in the field and have handling characteristics similar to portland cement. Thus, they are generally compatible with the PCC substrate. The main disadvantages may be occasional poor bonding characteristics, slow strength gain, high modulus of elasticity, high abrasion loss, and/or excessive shrinkage and cracking.

1. Portland Cement-Based Materials

Portland cement-based patching materials have an advantage that the final patch and the PCC substrate will have nearly identical thermal properties and chemistry. Portland cement also has the advantage of a well-controlled, large production industry that has been thoroughly researched and studied for nearly every conceivable property and "fine-tuned" to maximize performance. The thermal compatibility reduces the stress transmitted to the bond line and results in a relatively homogeneous structural section. Portland cement is often modified to increase early strength gain by adding chemical admixtures, calcium chloride, or grinding the cement finer. However, the initial drying shrinkage is high so proper curing is essential. Unfortunately, PCC does not always bond effectively to hardened PCC substrates.

Portland cement concrete is typically the most inexpensive patching material except for possibly asphalt concrete. Asphalt concrete has served as an effective temporary patch, but is usually not permanent. The history of using asphalt concrete as a PCC patching material has been well documented and will not be addressed here.

Portland cement set time can be accelerated by adding calcium chloride or several proprietary chloride-free accelerators. The chloride-free accelerators must be specified when the repair is near reinforcing steel since free chloride or sulfate ions will accelerate the corrosion of the reinforcing steel. Typical compressive strengths of PCC accelerated with calcium chloride and a commercially available chloride-free accelerator are listed below for 8 sack PCC with 3/8" maximum aggregate:

	Compressive Strength (2" cubes) (psi)			
	3 hrs	6 hrs	24 hrs	7 days
2% by wt cement $CaCl_2$	---	425	3010	6495
4% by wt cement $CaCl_2$	180	855	3915	7215
Daraset (7% by wt cement)	---	240	4555	8315

Normally, traffic may be allowed on PCC accelerated with 4% $CaCl_2$ within four hours after mixing. Most of the commercial chloride-free accelerators presently available result in reduced initial strength gain so the time to traffic may be slightly longer.

Several patching materials utilize finely ground cement to accelerate set time. The finer particles provide greater surface area or more reaction sites for contact by water to speed hydration. These products are typical of Type III cements. Bonding properties and typical physical properties are generally not improved except for the increased strength gain rate. Initial drying shrinkage may be even higher, however.

These accelerated portland cement based materials establish a datum for all other patching materials. Patching materials must exceed the performance properties of accelerated PCC to be considered - surprisingly, many proprietary patching materials cannot.

Due to the poor bonding qualities, a bonding agent should be used. Typically, a prime coat of epoxy adhesive is applied prior to patching. This has been an effective method for patching spalls but problems with delamination have occurred in very large patches or overlays. The epoxy must be properly formulated to resist the thermal and shrinkage stresses. State specification 8040-21M-08 epoxy has performed well, but further research may improve performance and decrease cost.

2. Gypsum Based Patching Materials

Gypsum is largely composed of calcium sulfate ($CaSO_4$). Gypsum hardens by the hydration process and is, therefore, compatible with the hydration of portland cement. Some materials that were evaluated contained as much as 80% of gypsum as $CaSO_4$. The gypsum additive may cause the concrete mortar to be slightly expansive, which in controlled amounts is desirable in a patching material to counteract shrinkage. Gypsum reacts with tricalcium aluminate, thereby forming calcium sulfoaluminate. If the sulfate ion concentration is too high, destructive excessive expansion can occur. However, this destruction can be avoided by using a cement with a low tricalcium aluminate content (1).

Gypsum-based materials generally have very high early compressive strengths. Compressive strengths greater than 7,000 psi in 24 hours and over 12,000 psi in 28 days have been observed. Most other physical properties are similar to portland cement concrete. Bonding properties are fairly good to a SSD or dry PCC substrate. The long-term contact area or bond area of the gypsum-based concretes to PCC does not appear to disintegrate when continuously submerged in

water. However, gypsum-based materials have shown significant loss of compressive strength after prolonged exposure to moisture. Gypsum concrete has a high absorption rate, generally twice that of PCC, so it may show significant compressive strength loss if used in extremely moist areas.

Typically, gypsum-based materials have high concentrations of water-soluble sulfate ions present and should not be recommended for use near reinforcing or prestressing steel.

Due to the rapid setting characteristics, a cure seal is generally not required under normal conditions. Gypsum-based materials are usually inexpensive and may be the most cost-effective choice when not patching near reinforcing or prestressing steel.

3. Magnesium-Phosphate Patching Materials

Magnesium-phosphate concrete is produced by calcining mined magnesia, thereby forming magnesium and calcium oxides. The hardening reaction is initiated by adding phosphoric acid which yields magnesium phosphate and calcium phosphate. This is a chemical reaction and not a hydration reaction. The recommended mix proportions must be adhered to for best results.

Magnesium phosphate concretes bond very well to dry PCC substrates, but not as well to damp or wet PCC. Further, many of these concretes cannot tolerate moisture for as long as a week after placement without risk of debonding. This applies to a forced surface dried saturated substrate (SSD), as the moisture equilibrium, when restored, will result in debonding. Generally, no additional bonding agent is required, but epoxy primers have been used to help ensure the bond.

There are two types of magnesium phosphate concrete commercially available, one-component and two-component. The two-component consists of the dry material and a liquid component containing phosphoric acid. The single-component magnesium phosphate

contains a phosphoric acid in dry powder form and is activated with water. Magnesium phosphate concretes can be formulated for hot or cold weather use. Set times are typically 15 to 30 minutes. Most materials are self-leveling and, without modification, do not work well on steep slopes or vertical surfaces.

Water cannot be added to improve the workability of the two-component system. The two-component prepackaged materials are, therefore, limited in regard to workability. Prepackaged magnesium phosphate concretes may generally be extended up to 60% with sand-free pea gravel aggregate.

The preparation of the PCC substrate is very important for a successful patch. The bond surface must be abrasively blasted to provide surface profile and be clean and dry. Magnesium phosphate will react with aluminum so aluminum tools or mixing bowls should not be used. Excess surface water should not be added to aid finishing as this will result in a high water content at the surface and may result in high surface abrasion loss. Since reaction gases must be allowed to escape, curing seals cannot be used as they inhibit the hardening process.

The set time may be retarded by the addition of borax or other buffers. Laboratory tests indicate that one ounce of borax per 50 lb of mix will retard the set time five minutes at 72°F. If the material sets up too rapidly, a decarbonation reaction with the portland cement may occur and greatly reduce the bonding capacity. The carbon dioxide gases liberated by the decarbonation reaction cause bubbles to form at the bond line, thereby significantly decreasing the bonding area. (Figure 1). The decarbonation reaction effect may be mitigated by slowing the setting time of the concrete or by abrasively preparing the bonding surface removing most of the portland cement paste from the coarse aggregate at the bonding surface. Most magnesium phosphate patch failures are due to loss of bond. Bond failures are generally caused by poor workmanship, decarbonation, or moisture present in the PCC substrate at the time of placement.

Figure 1 - Photo showing decarbonation reaction on bond line of single component magnesium phosphate patching material magnified 28X.

Magnesium phosphate concrete will generally bond well to itself and can be used in freeze-thaw climates. Typical material costs currently range from $35 to $40 per cubic foot.

Magnesium phosphate concrete has much less shrinkage than PCC during hardening. This aids bonding in confined areas such as core holes and when grouting dowels.

Laboratory tests indicate that reinforcing steel cast in magnesium phosphate concrete does not corrode as rapidly as when cast in normal PCC. Therefore, the magnesium phosphate concrete is well suited for patching bridge deck surfaces and for bonding dowels.

4. High Alumina Cement Patching Materials

High alumina cements are produced by fusing limestone and bauxite in an electric or blast furnace; the clinker produced is then cooled and ground. Like portland cement, these cements gain their cementing strength by hydration with the addition of water. The water/cement ratio is more critical than for regular portland cement; therefore, it is important to follow the recommended mix ratios. As the name implies, the cement has a high concentration of aluminates. The calcium to aluminate ratio is typically 40:60 while normal portland cement is near 50:50 (2). During the hardening reaction, there are several reactions taking place simultaneously and the overall reaction is relatively complex.

Unmodified high alumina cement has a significant strength loss at high temperatures (over 135°F) when moisture is available. Under these conditions, the hardened high alumina cement concrete will undergo a crystalline conversion, a structure change that can result in a strength loss of up to 70%. The high alumina cement can be modified by adding calcium sulfate to reduce this strength loss.

The modified high alumina materials have rapid strength gain and the set times vary between 15 and 30 minutes, depending on

temperature. Set retarders and accelerators are available from some manufacturers. The setting time may be retarded by the addition of borax or accelerated by the addition of lithium carbonate. Several proprietary materials can provide compressive strengths in excess of 3,000 psi in three hours and 5,000 psi in 24 hours. Modified high alumina cements generally bond better to a damp substrate than magnesium-phosphate concrete, but both bond better to a dry substrate. Prepackaged modified high alumina materials are usually single-component and water activated. They may be extended up to 100% with 3/8" pea gravel aggregate. A cure seal is recommended when environmental conditions are hot, dry, and windy. The prepackaged materials are generally self-leveling but can be modified for low flow applications. Initial shrinkage is generally less than portland cement thereby increasing its compatibility with the substrate.

After a surface skin has formed, the material will not bond effectively to itself. Thus, for deep patches, it is recommended that the patch be placed in one lift to avoid possible delamination between lifts. Abrasive cleaning of the surface between lifts to eliminate the efflorescence will improve the bond if multiple lifts must be used. Laboratory corrosion tests indicate that the modified high alumina cement concrete has a tendency to corrode reinforcing steel more rapidly than normal PCC. However, further research is necessary to determine the significance of the increased corrosion potential. Costs of high alumina cement products, $25 to $30 per cubic foot, are generally slightly less than the magnesium phosphate products.

B. Organic Patching Materials

Organic patching materials, for the purpose of this discussion, will be broken down into polyester-styrene, epoxy, acrylic and urethane families. They all become hard by chemical reactions based on polymerization. Most organic polymers tend to have high initial shrinkage and a high thermal coefficient of expansion. Intimate contact between the resin and bonding surface is required for proper bonding. The aggregate loading (content)

should be as high as feasible to increase the thermal compatibility with the PCC substrate. Filler aggregate should be hard, nonabsorptive and rounded as rounded aggregate increases workability and nonabsorptive aggregate will decrease the total resin demand.

The set times of all the organic materials discussed are temperature sensitive. As the temperature increases, the working time and set time decrease for both inorganic and organic compounds. However, the organic compounds are generally much more sensitive to temperature. None of the organic polymers discussed require a curing seal. Most of the materials exhibit excellent freeze-thaw resistance. Most polymers are impermeable to water and road salts, so they are well suited for rapid repairs on bridge decks.

General Introduction to Polymers

Polymers are materials of repeating molecular structural units formed by polymerization. Polymer resins can be made from either a) monomers - all from one molecular family or b) comonomers - which means more than one molecular family is present. A liquid monomer may be polymerized by adding a hardener/promoter system, by heating, or by radiation. Polymer refers to the large molecules constructed of many repeating units.

The polymerization reaction is initiated by a free radical reaction. The initiator ruptures an unsaturated double bond of a resin molecule forming a free radical and initiates a chain linking of the molecules. The process continues to form long chains of molecules, often with crosslinking between chains to form a three dimensional lattice structure. Thermoplastic resins do not, however, have significant cross-linking between chains. They can generally be dissolved in a solvent and are usually melted for molding. Thermosetting polymers are heavily cross-linked. They will not melt, so they cannot be molded in this manner.

Appropriate safety precautions should always be observed when working with organic polymers. Manufacturers' material safety data sheets should be requested before using any polymer resins. Skin contact with all

organic polymers should be avoided.. Precautions on inhalation should be observed for a number of the resins. Solvents, such as acetone, are generally used for tool cleanup and constitute an exposure and fire hazard. Chlorinated hydrocarbon solvents are not recommended because of toxicity. Soap and water wash is always recommended after solvent cleanup.

1. Epoxy Based Patching Materials

The term epoxide relates to all cyclic ethers and specifically oxacyclopropanes. They harden by polymerization, forming a free radical by opening a three member ring (3). There are several reaction mechanisms that may occur so epoxies may have very different final properties. Before choosing an epoxy patching material, a testing program addressing strength gain, bonding ability, elasticity, thermal properties and water sensitivity is strongly recommended.

When using an epoxy patching material, the PCC substrate must be dry and clean. Grease, oil and loose particles must be removed. An aggressive macro and microtexture for bonding is recommended. Epoxy patching materials are generally well suited for tapers and featheredging. Most prepackaged materials can be extended with pea gravel up to 50% if additional epoxy binder is available.

Epoxy cure rates vary dramatically - from minutes to days. Epoxies generally are relatively slow setting and continue to gain strength for weeks. However, they can be formulated to support traffic within two to three hours.

Epoxies are usually formulated in two-component systems mixed 1:1 or 2:1. They have relatively low initial shrinkage, good adhesion properties, and excellent chemical resistance, but are not tolerant to deviation from the designed component ratio. The two components must be mixed within 10% of the specified ratio or a significant decrease in strength and other property changes may occur.

Epoxy resins tend to have high viscosity and a putty-like mortar consistency that may be sticky to finish. Abrasion resistance is generally very good. Large epoxy patches may present a skid resistance problem. Texturing may be required or suitable aggregate broadcast onto the surface before the resin sets to increase skid-resistance. Epoxy resins are impermeable to water and chlorides. Protective clothing is recommended to prevent prolonged contact with the skin. The main drawback to the use of epoxy resins is that they tend to be very expensive. Prices for epoxy concrete vary greatly but are generally over $100 per cubic foot.

Epoxy resins are excellent adhesives. They usually work well for thin skin patches or for sealing large uncontaminated structural cracks. Epoxy specifications should be based on the specific use for which the epoxy is intended.

2. Methacrylate Based Patching Materials

This section will address methyl methacrylate (MMA) and high molecular weight methacrylate (HMWM). Methyl methacrylate has been used in the polymer concrete industry for many years. High molecular weight methacrylate is a recent development as a result of this research project. The MMA is much more volatile and higher fuming than the HMWM. The HMWM is much less flammable than the MMA, so it is safer to use. A comparison of the MMA and HMWM resin properties is presented in the section of this report entitled, "Crack Sealing With High Molecular Weight Methacrylate".

a. Methyl Methacrylate Patching Material

Methyl methacrylate (MMA) will provide between 30 and 60 minutes of working time, then cure very rapidly. Typically, MMA concrete develops compressive strengths of 5,000 psi at three hours and 9,000 psi at 24 hours. The flexural strength at 24 hours is over 2,000 psi. Methyl methacrylate bonds very well to a dry PCC substrate. The PCC surface should be abrasively cleaned

and an MMA primer applied. Bonding to wet or SSD PCC has not been satisfactory. The material has excellent abrasion resistance and is self-bonding. As with all of the organic polymers, no cure seal is required.

Extended exposure to the vapors may cause dizziness, headaches or nausea. Contact with the skin may cause a rash and should be avoided. The resin is flammable, so open flames must be avoided. The cured resin will burn, but will not sustain combustion. The proper safety equipment must be used and safety precautions followed when working with methyl methacrylate concretes.

Methyl methacrylate concrete is generally less expensive than epoxy concrete, but still can cost as much as $100 per cubic foot. Most of the prepackaged materials can be extended up to 50% with dry pea gravel.

b. High Molecular Weight Methacrylate Patching Materials

To avoid the volatility and safety concerns associated with MMA, a new methacrylate binder (HMWM) was developed. The resin can be purchased in bulk. The catalyst system consists of two parts. A metal drier, usually cobalt naphthenate, is added to the resin and thoroughly mixed. This reduces the required activation energy of the polymerization reaction. To begin the hardening reaction, an organic peroxide is then added and mixed into the resin. Well-graded aggregate is then added to the resin to produce a polymer concrete.

A flexible resin formulation is preferable to reduce differential thermal stresses at the patch or overlay. The discussion and strength data presented in the High Molecular Weight Methacrylate (HMWM) Concrete Overlays section of this report are applicable for use as a patching material.

The monomer properties and a discussion of the polymerization reaction are covered in the section of this report entitled Crack Sealing With High Molecular Weight Methacrylate.

The resin has a very low viscosity and excellent wetting characteristics. It also has low initial shrinkage and excellent bond to dry or SSD substrates. The high solvency capacity will allow it to bond through thin grease and oil stains. High Molecular Weight Methacrylate (HMWM) concrete bonding strength usually exceeds the shear strength of the PCC substrate. A prime coat of resin is recommended prior to patching to avoid a withdrawl of resin from the HMWM concrete. The HMWM concrete typically has a working time of approximately 30 minutes. The compressive strengths are generally greater than 5,000 psi in three hours and over 10,000 psi in 24 hours. The flexural strength is approximately 2,500 psi in three hours. Traffic generally can be allowed on the patch within two hours after pacing. The set time is temperature-dependent, but can be somewhat controlled by the percent hardener/peroxide added.

High Molecular Weight Methacrylate concrete is impermeable to water and chlorides. The polymer bonds well to PCC, steel or aluminum. Cleanup may be done with water or solvents.

The concrete aggregate to be combined with the HMWM must be dry. The aggregate grading listed in the HMWM Concrete Overlay specification provided in Appendix 2 appears to be optimum. The cement or fly ash present acts as fine aggregate and does not hydrate. For small jobs, using dry bagged concrete for aggregate works very well. One 100 lb sack of concrete mix combined with one gallon of HMWM resin yields a workable polymer concrete.

3. Polyester-Styrene Concrete Patching Materials

Polyester resins are among the most versatile synthetic polymers and the most commercially available. The resins studied as part of this project were unsaturated polyester dissolved in styrene. Unsaturated means that the double bonds that exist in the backbone of the monomer molecules are capable of undergoing additional polymerization in subsequent cross-linking reactions. The styrene monomer is used as a solvent to decrease the viscosity of the polyester resin and the polyester and styrene undergo copolymerization.

The types of polyester resins that have been investigated during this project are isophthalic, vinyl ester, and fumarate based. These base groups are listed in increasing order of bonding strength, chemical resistance and cost. Polyester resins are normally formulated with hardeners prior to shipping, but may be obtained without the metal drier hardener.

The work done under this research project has shown that polyester-styrene concrete has excellent potential for patching and overlaying PCC concrete. The performance of past systems has been greatly improved by the addition of one-half to one percent silane coupler. The silane coupler specified is an organosilane ester, gamma-methacryloxypropyltrimethoxysilane. The addition of the silane has greatly increased the bonding strength to siliceous aggregate and to the PCC substrate. An in-depth discussion of the polyester-styrene resin is included in the section of this report entitled Polyester-Styrene Concrete Overlays.

The concrete mix design specified for patches and bridge header repairs is similar to the overlay mix design specified. Thus, the discussion on polyester-styrene concrete for overlays applies equally to patching spalls or headers. Incidently, the HMWM resin is an excellent primer for polyester-styrene concrete.

Headers are used to prevent asphalt concrete overlays from migrating into bridge expansion joints and to structurally support joint sealers. With the relatively flexible asphalt concrete on each side, the header is subjected to high impact loadings. Very few materials have been successful in the past. Interestingly, several Caltrans maintenance districts are now specifying polyester-styrene concrete for header repairs. Most repairs of this type have been very successful.

The current material cost for producing polyester-styrene concrete is approximately $16 per cubic foot, making it one of the most inexpensive polymer patching materials.

In general, the vapors are not hazardous, but the styrene monomer is very volatile and the fumes may be obnoxious. Workers may develop a skin sensitivity and extended inhalation may cause dizziness and headaches. Toxicity information should be reviewed prior to use and good industrial hygiene must be observed. Material data safety sheets should be requested whenever a new chemical formulation is used. The unpolymerized resin is flammable, so appropriate safety precautions must be observed. Resin should be mixed in small batches, typically five-gallon batches, to reduce safety hazards. Surface preparation, mixing, and finishing are all similar to that for polyester-styrene concrete overlays.

Further research is required to determine the polyester group chemistry and physical characteristics that will result in optimum performance. This future research could include adding reclaimed rubber particles (as aggregate) to obtain increased flexibility and energy absorbing capacity. Further research regarding the use of wetting or deaeration agents is also required.

4. Urethane Patching Materials

Work has been initiated at TransLab to determine the feasibility of using low viscosity urethane resins as polymer concrete patching materials. Urethane resins tend to expand uncontrollably when mixed

with a well-graded aggregate. The expansion was reduced when the fines were eliminated and a coarse uniformly graded aggregate was used. The open graded aggregate allowed the outgassing bubbles to rise to the surface and dissipate, greatly reducing expansion. Omitting the fines did, however, increase the percentage of resin required for a workable concrete and, hence, its cost.

Caltrans is currently evaluating the use of urethane resin for emergency spall repairs under traffic conditions. Urethane resin set times can be formulated to be as rapid as three seconds. Aggregate is placed to grade in the spalled area and the urethane resin is then flooded into the spall using a two-component mixing gun. This method is similar to the emergency bomb crater repair used for military aircraft runways.

The advantages of a urethane patching material are 1) set times may be controlled to support traffic within five minutes or less, 2) it may be used in cold or wet conditions, 3) minimal surface preparation of the spalled area is required, 4) its low viscosity allows the urethane to penetrate into cracks around the spall and may reconstitute and harden the PCC surface, 5) it bonds well to PCC and AC, and 6) it is relatively easy to place.

Accurate cost estimates are not available since the research into optimum mix formulations is just beginning. It is estimated that the costs will be similar to the polyester-styrene resins.

Two field trials have utilized urethane for rapid spall repair on PCC and AC pavements. Photographs of the repairs are included in Figures 2 through 4. Lane protection was provided and the time required for the patch to support traffic was approximately five minutes. All rapid repairs to asphalt concrete and PCC pavements are performing very well.

A summary of the typical physical properties of the patching materials by generic families is listed in Table 1.

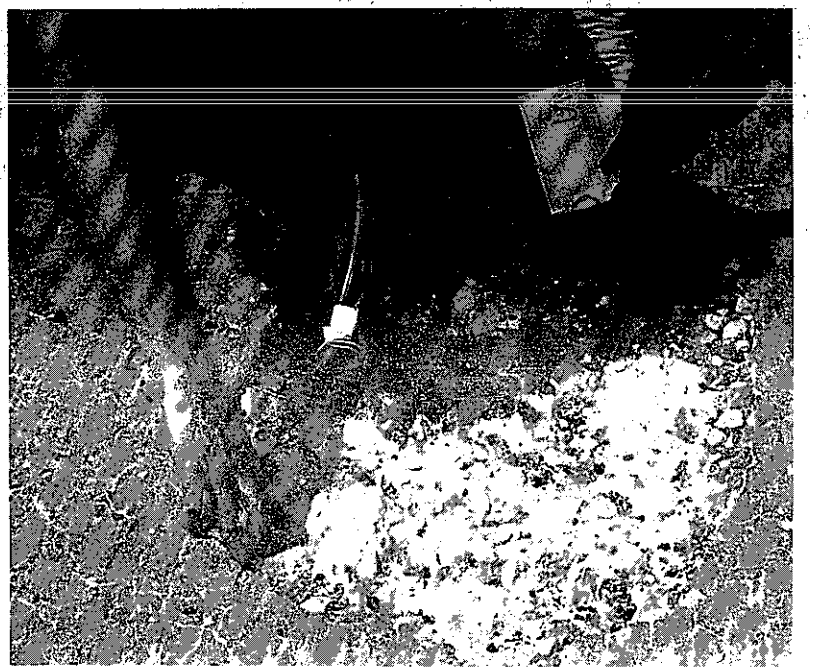


Figure 2 - PCC pavement spall due to alkali-reactive aggregate.

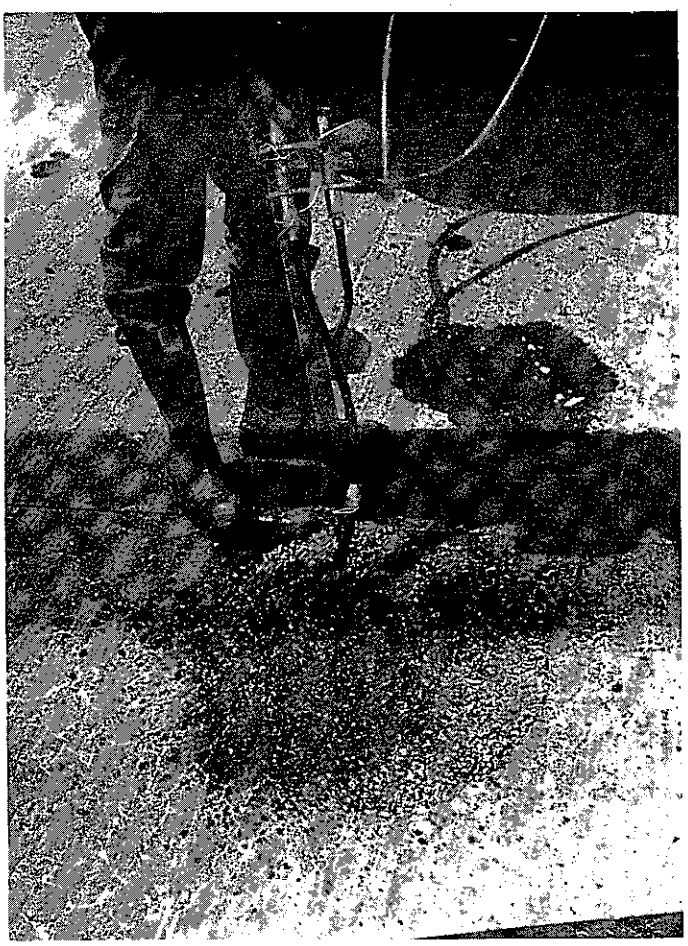


Figure 3 - Filling pothole with fast setting two-component urethane. Aggregate was preplaced.

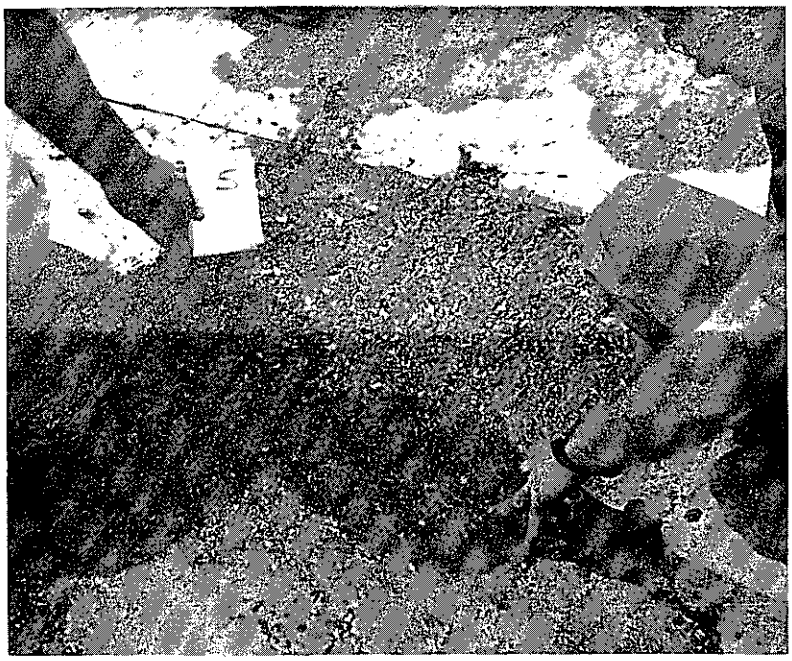


Figure 4 - Spall after resin polymerized. Patch will support traffic within three minutes

TABLE 1

TYPICAL PROPERTIES OF RAPID SET PATCHING MATERIALS BY GENERIC FAMILY

MATERIAL	APPROXIMATE WORKING TIME (MIN.) 72°F	APPROXIMATE TIME TO TRAFFIC (MIN.) 72°F	SURFACE PREPARATION	COMPRESSIVE STRENGTH (PSI) 3 hr	COMPRESSIVE STRENGTH (PSI) 24 hr	ABRASION LOSS (GRAMS) 24 hr	FLEXURE (PSI) 24 HR	BOND STRENGTH (PSI) 24 hr Dry PCC	BOND STRENGTH (PSI) 24 hr Wet PCC	"E" (PSI) 24 HR	CURE REQUIREMENTS	COMMENTS
INORGANIC												
1) PCC w/accelerator	120	300	Surface abrasively blasted and clean. Epoxy prime coat required.	–	3100	22	425	300	350	1.5×10^6	Cure compound or water cure.	Inexpensive, slow strength gain.
2) MAGNESIUM PHOSPHATE	15	60	Surface abrasively blasted and clean, must be dry.	4000	6000	25	800	475	160	4×10^6	No cure permitted.	Subject to decarbonation at bond line and cracking.
3) HIGH ALUMINA CEMENT	15	60	Surface abrasively blasted and clean.	5000	6500	20	600	400	375	4×10^6	Normally not required. May need cure in hot wind.	Subject to cracking, forms surface skin.
4) GYPSUM BASED	20	60	Surface abrasively blasted, clean and damp.	3500	6000	18	400	300	375	2.3×10^6	Not required under normal conditions.	Should not be used when it will be in contact with rebar; suitable to use in dry climates; bonds well to both dry and SSD surfaces.
ORGANIC												
1) URETHANE	5-15	30	Surface abrasively blasted, dry and clean.	2000	4500	3	1600	Failed in PCC	500	0.3×10^6	Not required.	May be formulated for very rapid setting, some resins are moisture sensitive, may require formulation.
2) METHACRYLATE a) Methyl-methacrylate	30	90	Surface abrasively blasted, dry and clean.	7000	8000	10	2000	Failed in PCC	Failed in PCC	3.4×10^6	Not required	High fuming may cause nausea in workmen, flammable, solvent cleanup.
b) High Molecular Weight Methacrylate	20	60	Minimal preparation of bond surface. No surface moisture present.	5000	10,000	5	2500	Failed in PCC	Failed in PCC	3.5×10^6	Not required.	Excellent bonding strength in damp and dry conditions; may require formulation, excellent for thin tapers.
3) POLYESTER-STYRENE	20	60	Surface abrasively blasted, dry and clean.	3000	7000	3	1600	Failed in PCC	Failed in PCC	2.2×10^6	Not required.	Resin readily available, concrete requires formulation, solvent cleanup.
4) EPOXY	20-30	60-90	Surface abrasively blasted, dry and clean.	2000	10,000	negligible	2400	Failed in PCC	Failed in PCC	4.2×10^6	Not required.	Sticky to finish, expensive. Excellent bond and durability.

Corrosion Potential of Selected Rapid Patching Materials

The possibility of reinforcing steel damage due to the corrosive effects of certain rapid set materials for structural repairs was evaluated. This evaluation consisted of measuring the pH of the rapid set materials to one year of age and measuring half-cell potentials in samples submerged in salt water.

The pH of a patching material indicates, to some extent, its corrosive potential when in contact with reinforcing and prestress steel. Most steels, in concrete, corrode by oxidation. This oxidation results in the increased volume of matter around the steel. This expanding product often fails the concrete surrounding it. Given sufficient concrete thickness, the oxygen, water, and chloride penetrations from the environment will be reduced and the corrosion process will be retarded.

In portland cement concrete, the higher the pH, the better the corrosion protection. The hydroxide passivity of the metal's surface prevents oxidation at pH above 8.5. Low carbon steel embedded in portland cement concrete in a non-chloride, non-sulphate environment has no tendency to corrode (4).

However, regardless of pH, many rapid set materials contain enough chlorides or sulphates to cause corrosion. A test was conducted on two materials that demonstrated good physical characteristics for rapid set materials. The test consisted of two evaluations; one was the pH of aged "hydrated" concretes, and the other was the pH and calomel half-cell potential of freshly placed material.

The first phase of evaluation consisted of pulverizing aged samples of magnesium phosphate (MagPhos), modified high alumina cement (MHAC),and PCC. These were individually mixed with distilled water and the pH was determined using a pH meter. The second phase consisted of mixing and casting the rapid set materials and immediately placing the resulting specimen in a container with 3.5% NaCl solution. The pH was measured during the "hydration" period from mix time to 72 hours, both at the surface and interior through plastic tubes set onto and into the casting. A second test was done by casting the materials individually with a metal bar imbedded, then placing these samples in a 3.5% solution of NaCl. Calomel electrodes were immersed

and readings taken between the electrode and the metal bar. These tests were conducted by George Chang, P.E., of the TransLab Corrosion Section. His efforts are greatly appreciated by the authors.

The pH data for MHAC in Figure 5, "Summary pH Value Test Results," range from 9.9 to 11.9. This is very near the 12.2 values for PCC and implies good protection. However, the calomel half-cell potential (Figure 6) indicates a voltage as high as 700 millivolts in comparison to about 600 millivolts for PCC. This implies that the MHAC provides less protection from corrosion than that afforded by PCC (4).

The MagPhos has a much lower pH than the MHAC and is, in fact, sometimes within the acid region with a pH ranging from 5 to >10 (Figure 5). The difference in pH between the concrete surface and interior is probably due to the ammonia product escaping and being trapped. The ammonia is itself a rust-preventative for two reasons - the ammonia passivates the metal surface and the overall pH is high.

Figure 5
SUMMARY - pH VALUE TEST RESULTS
OF PATCHING CONCRETE - MagPhos and MHAC

I. MagPhos Phase I: pH Value Obtained from Old Precast Samples

Samples	pH Value	
	Powdered Sample in Distilled Water	Sample Sealed & Soaked with Equal Volume of Water for 2 Days
Neat MagPhos - 35 days old	8.3	10.2
Neat MagPhos - 1 year old	10.1	10.1
30% MagPhos 50% P.G. - 1 year old	7.8	10.3
7 Sack Regular PCC 1 yr old (Control)	12.2	12.2

II. MagPhos Phase II: During Hydration Period in 1000 mls of 3.5% NaCl Solution

Age from the adding of mix water	Average Sample from Top Surface of Hydrating MagPhos	Average Sample from Inside of Hydrating MagPhos
10 min	5.2	6.3
3 hr	5.3	7.2
24 hr	5.4	9.6
48 hr	5.3	9.9
72 hr	5.3	10.2

III. MHAC: During Hydration Period in 1000 mls of 3.5% NaCl Solution

Age from the adding of mix water	Average Sample from Top Surface of Hydrating MHAC	Average Sample from Inside of Hydrating MHAC
10 min	10.5	10.4
1 hr	10.5	11.2
24 hr	10.5	11.2
48 hr	10.5	11.3
72 hr	10.4	11.3

Note: MagPhos = Magnesium Phosphate - Water Activated
MHAC = Modified High Alumina Cement

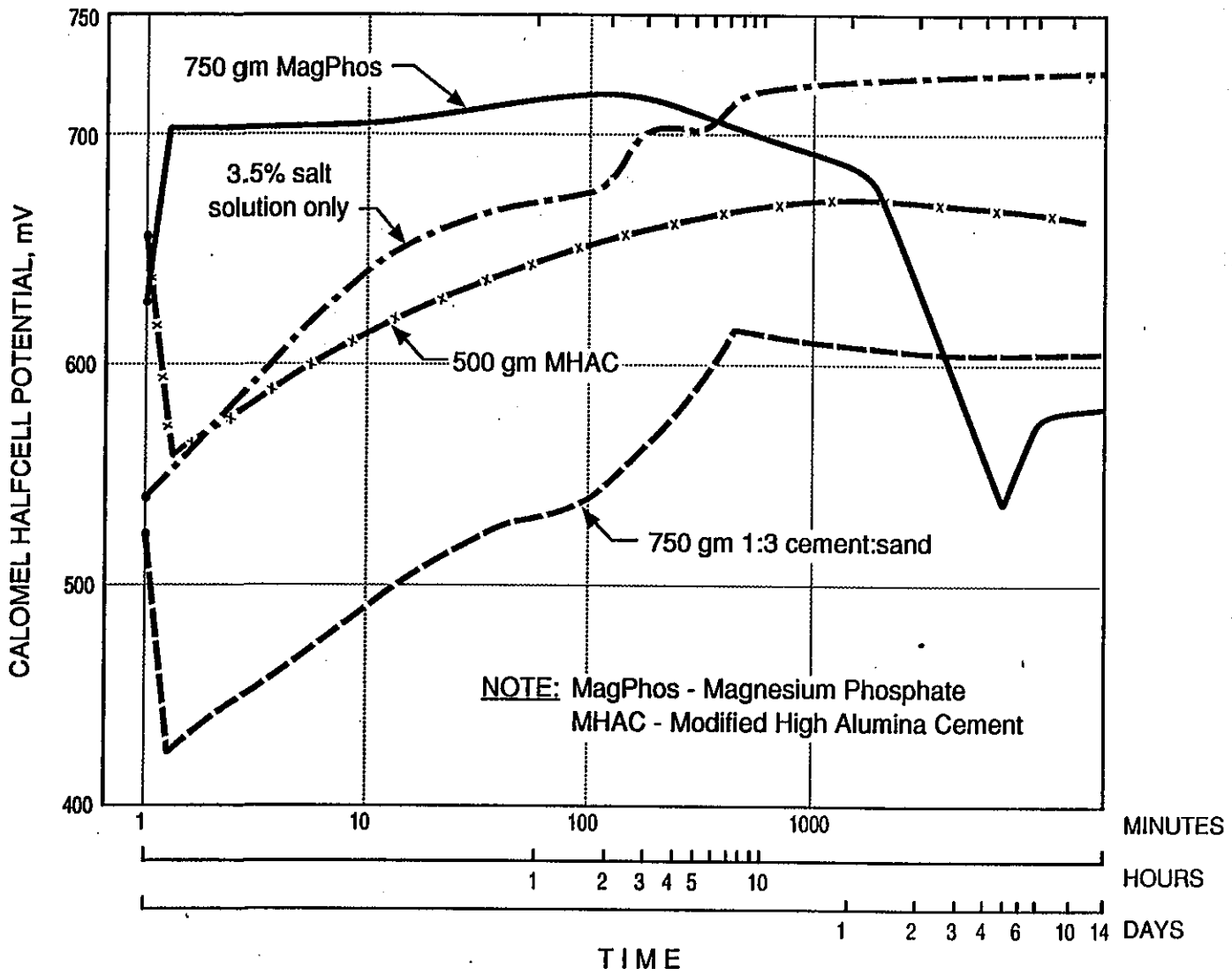


FIG. 6. PATCHING CONCRETE CORROSION STUDY CALOMEL HALF-CELL POTENTIALS OF STEEL DURING HYDRATION IN 1000 mls 3.5% SALT SOLUTION

Further, the phosphoric acid anhydride used in MagPhos rapid set materials is also a corrosion inhibitor. This is similar to the process known as "parkerizing" within the industrial sector.

As Figure 7 indicates, the freshly cast MagPhos reaction begins at a low pH of 6, which is acidic. As the reaction continues the pH rises well into the basic range. The effect on steel is demonstrated in Figure 6 where the half-cell voltages begin at 625 mv, immediately rise to 700 mv within minutes, and then fall to 500 to 575 mv within a few days. Thus, the phosphoric acid reaction occurs first by attacking the steel while the concrete reaction goes to completion, resulting in a highly passivated metal surface. The concrete reaction then releases ammonia and the pH of the system rises and remains high. The resulting low mv readings (lower than PCC) indicate corrosion mitigation.

Exterior readings from the MagPhos as indicated in Figures 5 and 7 are unexpected, and no explanation can be given.

It is concluded the modified high alumina rapid set materials may not protect the steel from corrosion as well as portland cement concrete whereas the magnesium phosphate rapid set materials may provide a greater corrosion protection than portland cement concrete.

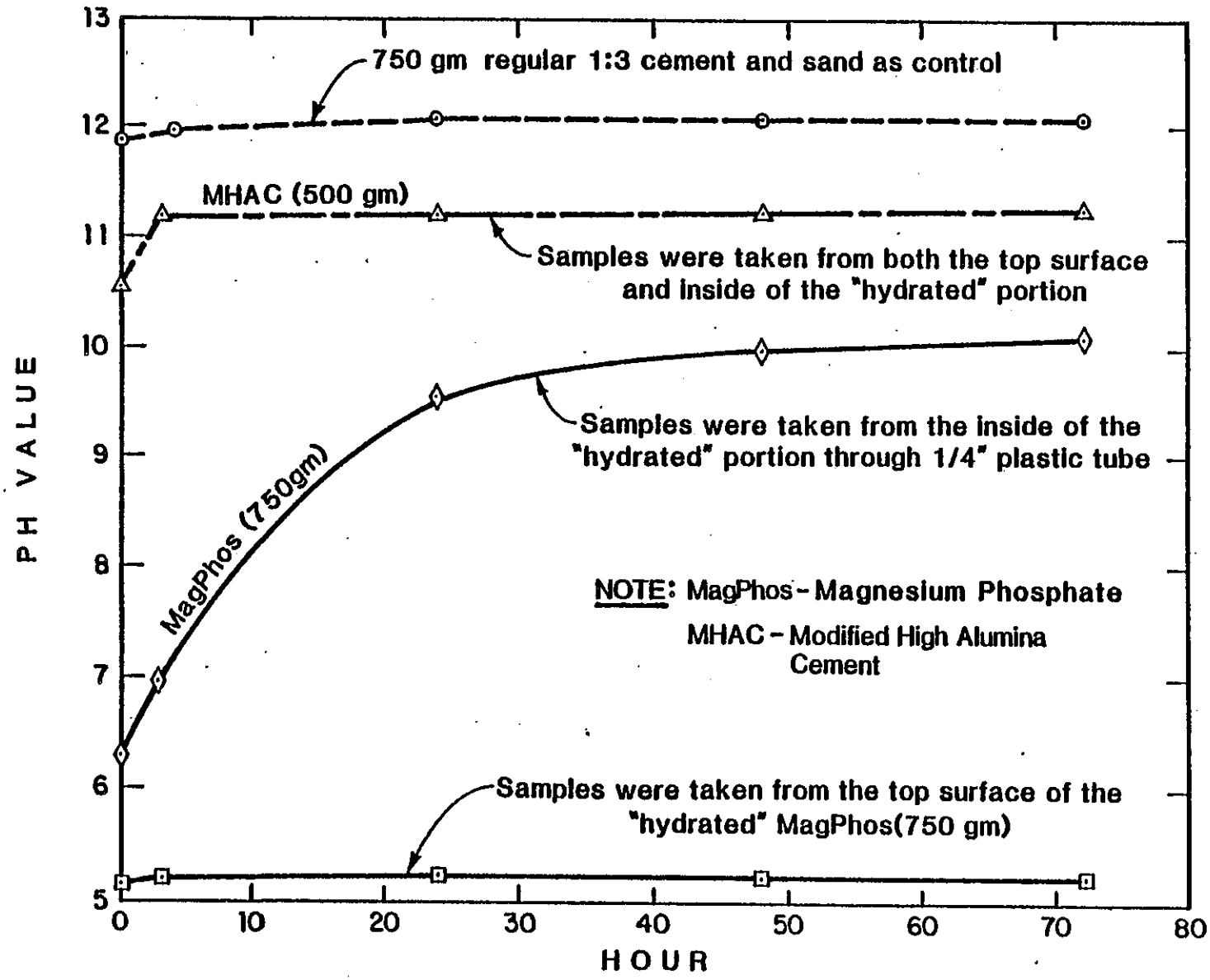


Fig. 7. PATCHING CONCRETE CORROSION STUDY
PH VARIATION DURING HYDRATION IN
1000 mls 3.5% SALT SOLUTION

TEST METHODS FOR RAPID SET PATCHING MATERIALS

For the purpose of this report, rapid set patching materials are considered those materials that will support traffic within four hours of placing. If more than four hours are available for setting and curing, there are numerous additional options including portland cement concrete. The specification for rapid set patching materials is included in the appendix.

Numerous comparative laboratory tests were developed to evaluate patching materials. Testing for contract compliance is done in two stages. Stage I includes chemical analysis, set time, workability, abrasion resistance, and compressive strength gain. Stage II testing includes flexural strength, bond to SSD and dry PCC, modulus of elasticity, moisture sensitivity, absorption, and freeze-thaw resistance if applicable.

Stage I Testing

Chemical Analysis

A chemical analysis is run to identify the basic type of material. This may also identify any potentially hazardous materials present and the quantity of chlorides or sulfates that may accelerate corrosion of reinforcing steel. If the patch will be near reinforcing steel, Caltrans current specification calls for less than 0.05% of soluble chlorides and less than 0.25% of water soluble sulfates of the hardened concrete.

A batch mix is made and tested for workability, set time, abrasion loss, and compressive strength gain. The materials are tested neat in Stage I when applicable. The test methods for workability (flow table) and compressive strength gain are included in the appendix under "Method of Test For Determination of Compressive Strength of Concrete Overlay and Patching Materials (Using 2" Cube Specimens)." Caltrans current specification for rapid set patching material requires a minimum compressive strength of 3,000 psi within three hours and 5,000 psi within 24 hours at a minimum flow of 1.10 at 10 drops.

Compressive Strength

The compressive strength values are often oversold by material salespersons. Patching materials rarely fail in compression. The compressive test is a relatively quick test and its main value is for quality control. Field experience has shown that 3,000 psi compressive strength is adequate to support traffic loadings by a patching material. The specification for 5,000 psi minimum compressive strength within 24 hours indicates that the patching material will have similar durability to sound PCC. The workability specification is required to show that the material can be placed and finished at a given consistency that will yield the required strength gain.

Set Time

The test method for set time is included in the appendix, titled "Method of Test for Determination of Set Time of Concrete Overlay and Patching Material by Gilmore Needles." The set time is currently specified at 25 minutes minimum.

The set time specification is required to provide adequate mixing and placing time before the material begins to set. If the material sets too quickly, it is not practical for use since it will not be able to be properly placed and compacted. Set time is usually directly related to temperature. The temperature at test is specified to be between 68 and 77°F. This temperature is considered to be median and modifications may be required to certain materials when used in hotter or colder environments.

Abrasion Resistance

California Test 550, "Method For Determining the Surface Abrasion Resistance of Concrete Specimens," is used to measure the ability of a concrete specimen to resist surface abrasion due to the impact of steel balls in the presence of water. Cylindrical test specimens, four inches in diameter and two inches long, are molded or are cut from hardened concrete. The specimens are brought to a saturated surface dry (SSD) condition and placed in test molds with eight steel balls and 200 ml of water. The apparatus vibrates with a

vertical throw of one inch at 1,200 cycles per minute for three minutes. The abrasion loss in grams is calculated by subtracting the weight of the SSD specimen after the test from the weight of the SSD specimen before test. Caltrans specifications require less than 25 gram loss when testing the neat material at an age of 24 hours. Fully cured seven-sack PCC generally abrades between 17 and 18 gram loss. This test eliminates materials that have very poor 24-hour abrasion resistance. Results obtained with this test method have correlated well with field experience when considering tire chain abrasion.

Stage I testing can generally be performed in approximately 24 hours. If the patching material is acceptable in Stage I testing, a larger concrete batch is then made for Stage II testing.

Stage II Testing

Stage II testing is performed on the material extended to the maximum manufacturer's recommendation with 3/8" pea gravel. Twenty-four hour values for flexural strength, bond to SSD and dry PCC, modulus of elasticity, absorption, and specific gravity are determined. If the material is to be used in a freeze-thaw environment, it must also be tested for freeze-thaw resistance. Additional testing may be required depending on the material being tested. Polymer resins may require testing for viscosity, vapor pressure, flash point, tensile strength, elongation, and glass transition temperature. Methods for fabricating test specimens and determining bonding strength, modulus of elasticity, specific gravity, absorption, and flexural strength are included in the appendix.

Flexural Strength

Flexural tension tests are important for concrete testing since tensile stress is developed due to shrinkage, traffic loading, and temperature change. The general rule that the tensile strength of PCC is approximately one-tenth its compressive strength may not be valid for high strength patching materials. Cracks in concrete are caused by tensile failures. Failures in nonreinforced concrete beams are always tensile. To avoid premature cracking of the patching material, it is, therefore, important to consider not only the tensile

strength of the material but also the environmental conditions and the traffic loadings.

The California Test 551 "Method of Test for Flexural Strength of Concrete Overlay and Patching Materials", using three inch x three inch x 12 inch test specimens, is included in the appendix.

The modulus of rupture is expressed as the maximum bending moment multiplied by one-half the depth of the beam and divided by the moment of inertia of the cross section. This assumes that the stress varies linearly across the cross section. Since that is not true, the computed value is always greater than the actual stress.

Caltrans specifications require that the 24-hour flexural strength be greater than 500 psi. This specification has been developed through experience. Fully cured six-sack PCC generally has a flexural strength near 500 psi.

Bonding Strength

The bonding properties of a patching material are of utmost importance. If a material does not bond well to the PCC substrate, it will not remain in place long. High compressive or flexural strengths are of little value if the material has dislodged and is causing a hazard because it did not bond to the PCC pavement. The bonding test is used to measure adherence to both SSD and dry PCC.

Seven-sack PCC with one inch maximum aggregate is cast in 3 inch x 3 inch x 12 inch molds for bonding blanks. The concrete must reach a minimum compressive strength of 4,5000 psi within 28 days. The PCC test specimens are moist cured for 28 days, then room cured for approximately six months. The PCC blocks are then cut in half with a diamond blade saw to obtain two three inch x three inch x six inch bars. The cut face is used as the bonding surface. This surface effectively exposes both cement mortar and aggregate surfaces and has no appreciable macrotexture which, if specified, would be nearly impossible to reproduce. Sandblasting of the bonding surface is not done since this would also result in a nonreproducible surface.

The diamond cut surface has provided consistent, reproducible results. Also, the test bond strengths are conservative considering the aggressive surface texture specified for the substrate during construction.

For dry bonding strength, the PCC is oven dried before testing. For bonding to SSD concrete, the PCC blocks are soaked in water for a minimum of 48 hours prior to testing. The saw-cut PCC blocks are placed back into the molds and secured with the saw-cut end placed at least five inches from the end of the mold. The material to be tested is then cast against the PCC blocks. If a primer or bond coat is required, it is applied to the bond surface as recommended. The patching material is tested fully extended with filler as recommended by the manufacturer. The specimens are then broken at 24 hours in centerpoint loading. This loads the extreme fiber in tension which is the most common mode of failure of PCC. The specimen will fail on the bond surface, in the PCC blank, or in the patching material. A photograph of the testing apparatus is shown in Figure 8.

Caltrans specifications require a minimum bond strength of 400 psi to dry PCC and 300 psi to SSD PCC at 24 hours. In the field, 10 psi in bond strength is more than adequate, but zero psi is unacceptable - the patch is either bonded or it is not. Field experience indicates that if the material can meet these specifications and is properly placed, it should not delaminate. For very high-strength organic materials, other properties like modulus of elasticity shrinkage and thermal expansion should be considered to prevent the stress from exceeding the shear strength of the PCC substrate and causing delamination.

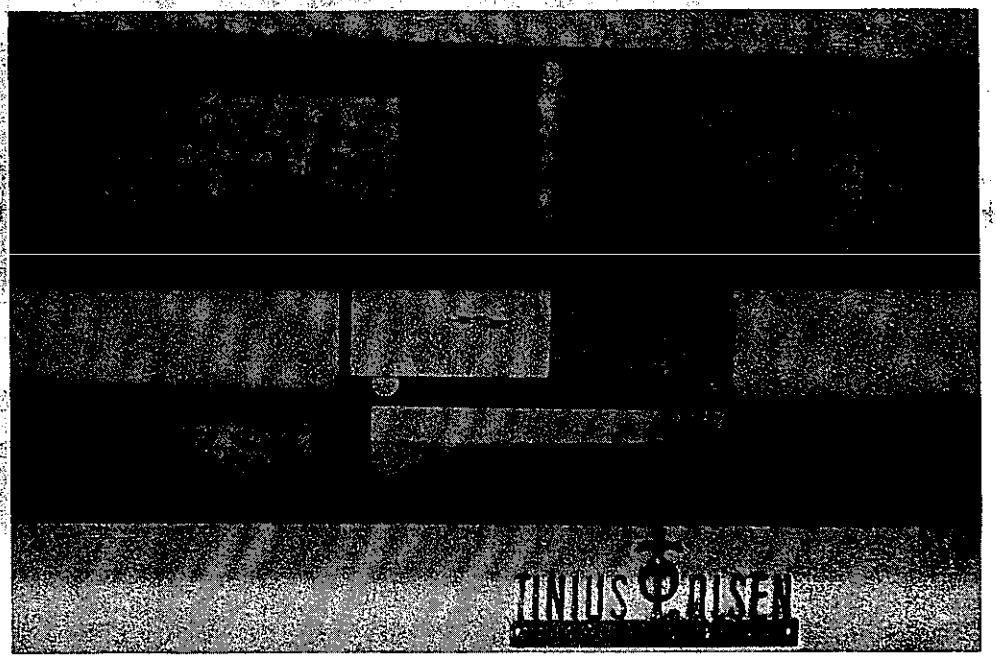


Figure 8 - Apparatus for bonding strength test in center point loading.

Additional Testing

Additional testing is often required beyond the specification compliance testing. New materials to be used to patch large areas or for use as an overlay material may require testing for freezing and thawing resistance, modulus of elasticity and thermal coefficient of expansion. When evaluating polymer materials, unfilled resin tensile strength, elongation, flash point, glass transition temperature, viscosity, and water sensitivity are important test parameters.

Modulus of Elasticity

A modified Caltrans test method for modulus of elasticity is provided in the appendix. The modulus of elasticity in compression gives an indication of the material's flexibility. Experience indicates that a material with a low modulus of elasticity is not likely to delaminate or crack. The lower modulus, more flexible materials will accommodate the thermal and loading stresses within the material rather than transfer the load directly to the substrate. The stresses may be accommodated by external dimension change or internal energy absorption due to the deformation of the molecular bonds. Materials that are too flexible may deform past the maximum yield strain and result in permanent loss of integrity. Skid resistance typically decreases as the modulus of elasticity decreases.

Patching or overlay materials that have a modulus of elasticity equal to or greater than that of PCC should be evaluated for possible problems due to the accumulation of stress that causes debonding or cracking problems. For organic resins, the elongation at ultimate tensile loading gives a good indication of the resin's relative flexibility.

Thermal Coefficient of Expansion

The thermal coefficient of expansion is used for the determination of stress and deformation due to temperature change. As the temperature changes, stresses develop. The determination of thermal stresses becomes more complicated when considering the relationship of the thermal coefficients of

expansion of the concrete's component parts. This becomes increasingly important when considering polymer concretes. The resin binder expansion may be magnitudes different than that of the aggregate filler. The closer the composite thermal coefficient of expansion of the overlay is to the substrate, the less the differential thermal stresses will be at the interface. Overlays are generally subjected to larger temperature variations than the substrates they are protecting. Thus, ideally, the overlay should have a thermal coefficient of expansion slightly lower than that of the substrate.

Glass Transition Temperature

The glass transition temperature of polymers must be considered. The glass transition temperature is the point at which the properties of the resin change from those of a brittle solid to those of a rubber. Above the glass temperature, the resin will have very different properties than when the resin is cooler. The modulus of elasticity, thermal coefficient of expansion, flexural properties, and compressive properties can change dramatically. Since many polymers have glass transition temperatures below 150°F, this property becomes significant for patching or overlays.

Freezing and Thawing Resistance

Freezing and thawing resistance must be considered for materials to be used in areas of California above the 3000 foot elevation. ASTM has several test procedures for measuring freezing and thawing resistance of materials. An accelerated bonding test has been developed by the Transportation Laboratory by subjecting overlay samples to freezing and thawing. One foot x one foot x three inch, 7-sack PCC blocks with a minimum of 6% air entrainment are cast and cured. The overlay system to be tested is then cast onto the cured PCC test block. The overlay is cured and two 4-inch diameter cores are extracted from opposite corners. The sample is placed in the freezing and thawing chamber while the cores are stored at room temperature. Freezing and thawing testing is conducted using ASTM C-666 equipment, with the test specimens immersed in water above the bond line.

The overlay sample is subjected to a minimum of 150 freezing and thawing cycles, then two 4-inch diameter cores are extracted. The four cores are then broken by the guillotine shear method and the appearance and shear strengths of each set of two cores are compared to determine the effect of freezing-thawing on the bonding of the overlay system.

CRACK SEALING WITH HIGH MOLECULAR WEIGHT METHACRYLATE

Introduction

Cracking in bridge decks occurs for numerous reasons such as cement mortar shrinkage, deflection stresses, fatigue, or reactive aggregate.

Past repair alternatives have been to do nothing, to fill the cracks by epoxy injection, or to overlay the deck. Most overlays add significant dead load to the structure. Epoxy injection has been unsatisfactory in sealing small cracks and is generally expensive. Thus, Caltrans has been experimenting with new methods to bond cracks together and reconstitute existing portland cement concrete bridge decks.

High Molecular Weight Methacrylate Monomer (HMWM)

Bridge deck cracks have been successfully mended by using a surface treatment of low viscosity HMWM resin. The monomer is catalyzed with a metallic drier (cobalt) and peroxide to initiate polymerization. The resin is then swept, squeegeed, or sprayed on the bridge deck at rate of approximately one gallon per 100 square ft. The resin flows into the cracks and polymerizes, filling and bonding the cracks together. A resin gel time of one hour or greater is recommended to allow time for the resin to penetrate the cracks before gelling. The low viscosity allows capillary action to fill cracks smaller than 0.5 mil. Dry sandblast sand is generally broadcast into the resin to improve skid resistance lost by the treatment. Traffic can usually be allowed on the deck within two hours after treatment. Material costs generally range from $.25 to $.30 per square foot.

The HMWM are unsaturated monomers of the methacrylate group, polymerizable with a free radical source and a metallic drier. The pot life is dependent on three parameters: a) temperature of resin, b) volume of resin, and c) percent initiator. The temperature of the bridge deck to be treated is an important parameter relative to the gel time of the resin. If the deck temperature is low, the resin may cure slowly, and if the deck is too hot, the resin may polymerize before it has a chance to penetrate the cracks. Generally, the resin, as formulated, may be effectively used between 45°F and 90°F. Accelerators or retarders may be required to obtain a gel time of approximately one hour. Manufacturers should be consulted for gel time versus temperature relationships. Also, the resin will polymerize slower in a thin film than in a large mass since the generation of the heat due to the chemical reaction will be less. Percent of initiator also has limited control over the set time.

The monomer has a low viscosity, low volatility, low initial shrinkage, high flash point, and high boiling point. Typical physical properties are listed in the specification for "HMWM Bridge Deck Treatment" in the appendix. The Brookfield viscosity of the resin is 8 to 20 cps or similar to that of diesel oil. This low viscosity, along with a low vapor pressure, is required for proper penetration into narrow cracks. The HMWM has a high solvent capacity to enable bonding through contaminated surfaces. For large cracks, a thixotropic agent may be added to increase the viscosity so that the resin will not flow out the bottom of the crack.

The HMWM should not be confused with methyl methacrylate (MMA). Methyl Methacrylate is far more volatile or higher fuming and has a distinct odor that is often objectionable to workers.

Since MMA is so volatile, it will evaporate before it polymerizes when placed in thin lifts on a hot bridge deck. When used to fill cracks in a hot bridge deck ebullition bubbles formed during polymerization resulting in an unsound repair. the HMWM has only a slight odor and is also much less flammable than the MMA. However, care should be taken to avoid prolonged skin contact with either resin.

The typical properties of HMWM and MMA monomers are presented in the following table:

Resin Properties	Methyl Methacrylate (MMA)	High Molecular Weight Methacrylate (HMWM
Viscosity (cps @ 70°F)	0.8	8-20
Density (lb/gal)	7.8	>8.7
Flash Point (°F) (PMCC)	51	>200
Vapor Pressure (mm) (Hg @ 77°F)	49	<1
Boiling Point (°C at 760 mm)	100	300
Shrinkage (%)	20	7-10
Odor	Strong	Slight

Field Trials

Hallelujah Junction Bridges - Long Valley and Evans Canyon

The first use of high molecular weight methacrylate resin for sealing cracks in bridge decks was on Evans Canyon U.C. (Br. No. 07-72L) and Long Valley U.C. (Br. No. 13-18L) on Highway 395 south of Hallelujah Junction (Highway 70/395) during October 1981.

A contract was initiated to seal cracks greater than 8 mils (0.008 inch) by injection with epoxy. The bridge deck of Evans Canyon U.C. was an experimental wax-bead entrained PCC known as internally sealed PCC. The cracks in this deck appeared very large so it was assumed that epoxy injection would be an appropriate remedy to prevent water and salt intrusion to the top mat of reinforcing steel and subsequent delamination. The contractor, however, found it impossible to inject any epoxy at the specified pressure of 25 psi. The contractor covered the crack surfaces with polyester and injected epoxy with pressures of 150-200 psi under the cover with essentially no

results. Examination of the cracks just below the deck surface showed cracks to be about 2 mils (0.002 inch) or less in width. Obviously, this was the reason for the epoxy injection failure on Evans Canyon U.C.

Shortly after the initial work on Evans Canyon U.C., operations were moved to Long Valley U.C. This bridge deck is also an experimental deck consisting of methyl methacrylate polymer impregnated PCC. The general appearance of this deck was not as bad as Evans Canyon U.C., but significant large cracks covered the deck. Again, attempting to inject these cracks failed. Subsequent examination revealed that these cracks were also less than 2 mils wide immediately below the surface.

At this time, a decision was made to attempt alternative crack sealing methods rather than simply abandoning the work. The only method that showed promise in the Transportation Laboratory's work was topically applied low vapor pressure, low viscosity, high molecular weight methacrylate.

The topical application was done through the use of squeeze bottles and batch mixing of the resin. The polyethylene squeeze bottles were standard laboratory ware and had a 4-inch long "kiwi-beak". This allows a controlled stream of resin to be directed into a crack fairly efficiently. The resin, initiated in 1000 ml (1 qt) batches that contained 15 to 30 ml (1 to 2%) cumene hydroperoxide (depending on air temperature) had a minimum gel time of 45 minutes. The cobalt naphthenate solution had been added previously at the rate of 250 ml to 5 gallons of resin. The high capillary action and low viscosity pulled the resin into cracks as small or smaller than 0.5 mil (0.0005 inch). Two or more treatments were needed to fill large cracks. Quite a bit of spreading or wetting of the deck surface occurred adjacent to the cracks.

The very low flammability of HMWM was clearly shown where the unsuccessful epoxy injection work was burned off with a propane burner to allow access into those cracks, adjacent to the HMWM work. The resin would burn in the propane flame, but extinguished upon removal of the torch. The entire job involved using 10 gallons of resin to cover 6300 sq ft of cracked deck containing about 12,000 lineal ft of cracks. Two men worked a total of three days each for five to six hours per day.

Cores (two-inch diameter) were taken to a depth of approximately three inches through the top mat of reinforcing steel. All four cores through a cracked section of Evans Canyon U.C. revealed complete crack penetration to the steel with a crack width of two mils at the top and less than 0.5 mil at the bottom.

Rio Vista Lift Span

The first Caltrans topical deck treatment using HMWM was in November 1981 on the Rio Vista Lift Span, 10-Sol-12-26.24. The Rio Vista Bridge, No. 23-14, has a 305 foot long x 26 foot wide x 6:5 inch thick lift span of lightweight PCC. The deck had extensive pattern cracking. During the rainy season, the lift span would gain weight due to the cracks filling with water and the lightweight aggregate absorbing moisture. A graphic example of this was the need to add weight to the counterweights each winter to compensate for the increase in weight of the lift span. Adding and removing the counterweights each year by manually moving 150 lb concrete blocks was labor-intensive, expensive and a safety hazard. The Transportation Laboratory (TransLab) was evaluating the HMWM monomers and recognized their potential for sealing cracks in PCC. On the morning of November 10, 1981, the eastbound lane was closed and the catalyzed monomer was squeegeed onto the deck. After the resin polymerized, the lane was opened to traffic and the westbound lane was treated. Sand was broadcast on the surface to reduce the residual tackiness due to the aerobic sensitivity of the resin. The aerobic sensitivity will cause the surface of the resin to set up much slower than the resin in the cracks. Broadcasting sand on the surface will prevent the resin from being tracked by traffic. The bridge was opened to unrestricted traffic by 4:30 p.m.

To date, the counterweights have not required adjustment and the treatment is considered a total success. The resin on the surface has worn off, but the cracks are still sealed and the porosity of the deck is still reduced. ASTM towed-trailer skid tests run on November 11, 1981, indicated that there was no decrease in skid resistance compared to adjacent PCC. It could be expected that new cracking would develop adjacent to the original cracking, but that has not occurred. Caltrans originally allocated $223,000 for a new deck, but the

topical treatment of HMWM successfully resolved the absorption problem for $6,850 including material, labor and traffic control.

This test indicates that the topical treatment with HMWM can be used to avoid an increase in dead loads during wet weather. The topical treatment should also restore the integrity of the PCC deck to its original condition. Further research is required to determine if actual bridge deck deflections are reduced.

Richmond-San Rafael Bridge

Further testing of HMWM for sealing cracks and patching spalls was initiated by Caltrans Bridge Maintenance Engineer Robert Bridwell on the Richmond-San Rafael Bridge in April 1983 and was finished in September 1983. He concluded in his report that HMWM was satisfactory for sealing cracked bridge decks, binding fine aggregate to the deck surface, and as a concrete binder for patching spalls. Gel times of the flood treatments were approximately 45 to 90 minutes at ambient temperatures of 65 to 76°F. Forty-five minutes is considered the minimum required gel time for successful penetration in most cases. Equal volumes of sand relative to resin appeared adequate to prevent tracking and to provide adequate skid resistance. Placing sand too soon may absorb the resin and prevent proper penetration. If the sand is placed too late, it will not adhere and may result in a skid resistance problem. Skid tests on the Richmond-San Rafael Bridge HMWM-treated sections indicated as good or better skid resistance than the adjacent untreated concrete deck.

Feather River Bridge

On May 24, 1983, a successful topical treatment of HMWM was applied to the deck of the Feather River Bridge, No. 12-134, 03-But-70-28.22. The bridge and railroad crossing was 21 years old. It has a lightweight concrete deck with a thin portland cement grout wearing course. The deck has suffered random cracking, possibly due to high deflections caused by traffic and train vibrations. The HMWM was applied with squeegees by Caltrans maintenance forces. The resin was mixed in five-gallon batches and placed at a rate of approximately one gallon per 100 square ft. A sand coat was applied to prevent tracking and to

provide a skid resistant surface. Air bubbles could be seen venting from the cracks as the resin displaced air, indicating resin penetration. This application appears to be satisfactory and will continue to be monitored for performance. Photographs of the application are included in Figures 9 through 14.

Thus, HMWM presents an opportunity to solve problems that previously had no satisfactory solution. Taking advantage of its low volatility and low viscosity, sealing both wide and narrow deck cracks, checks, and blemishes by squeegee or brooming is economically feasible. It is estimated that for $0.30 per sq ft for material, two workmen can cover a bridge deck of 5000 sq ft in one day.

A partial list of significant Caltrans projects involving HMWM flood treatments is presented in Table II. This is only a small portion of the decks that have been treated to date.

The HMWM resin is well suited for spray applications. TransLab has made numerous spray applications utilizing used automobile power steering pumps. These were chosen since they are relatively cheap and can be discarded after use. A practical way to spray the resin is to add the promoter to one half and the initiator to the other half and mix equal amounts at the nozzle. However, air atomization for spraying is not recommended; it should always be airless to avoid fog, or mist production, as much as possible.

Figure 9 - Catalyzing high molecular weight methacrylate (HMWM) monomer in five gallon batches.

Figure 10 - Broadcasting HMWM resin onto the Feather River Bridge deck.

Figure 11 - Brooming resin to fill surface cracks.

Figure 12 - Small spall repair
utilizing sandblast sand.

Figure 13 - Broadcasting sandblast sand on resin surface to increase initial skid resistance.

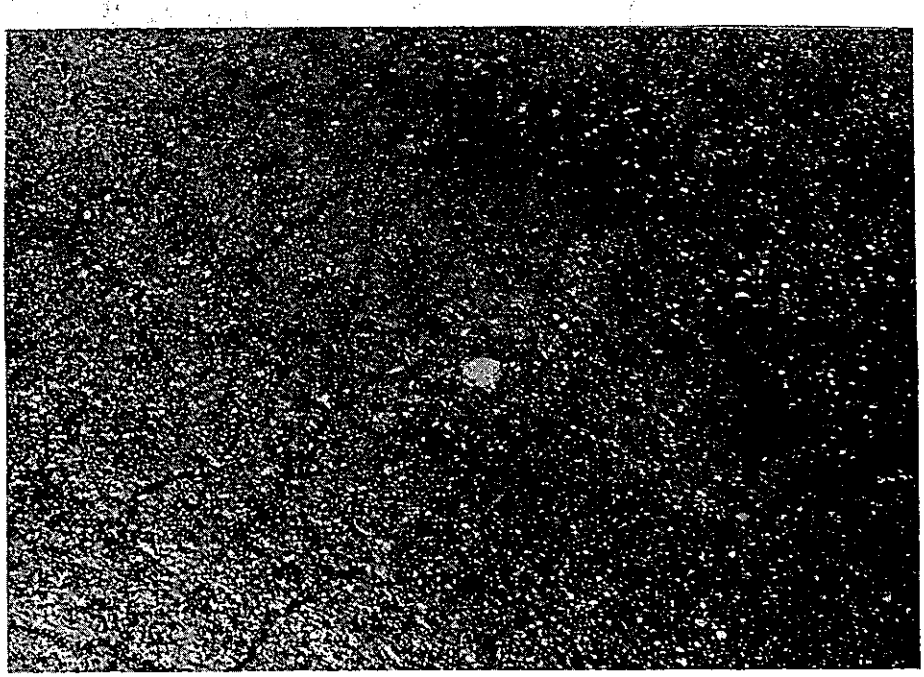


Figure 14 - Air being displaced by resin in a crack.

TABLE II

PARTIAL LIST OF METHACRYLATE BRIDGE FLOOD TREATMENTS MONITORED BY LABORATORY

1. Hallelujah Jct. Highway 395 (So. of Rte. 70) #07-72L, #13-18L, 10/6/81, sealed cracks only.

2. Rio Vista Lift span #23-14, 10-Sol-12-26.24, 11/16/81, flood treatment of lightweight aggregate PCC.

3. Lost River Bridge 1 and 2, 02-Sis-139, near Stronghold, CA, Summer 1983, flood coat and AC overlay.

4. Granada OC, #02-139, 02-Sis-5-51.16 EB, Fall 1982, flood treatment.

5. Ward Creek Br. #33-251, 04-Ala-17-14.18, Spring 1983, #2 lane NB, flood treatment.

6. Feather river West Branch #12-134, 03-But-70-28.22, 5/24/83, flood treatment of lt.wt. PCC with grout wearing course.

7. Richmond-San Rafael Br. #28-100, 04-CC, Mrn-17, 4/83-9/83, various locations, flood treatment.

8. Sacramento River Bridge at Dunsmuir NB, #02-2R, 02-Sis-5-2.65, Fall 1983, seal cracks only.

9. Big Bend Br. #19-122R, WB, 03-Pla-80-R65.0, October 1983, rebond delaminated PCC overlay.

10. Westacre U.C. #22-102R, 03-Yol-80-11.73, WB #3, February 1984, flood treatment.

11. Lost River Br. #2-59, 02-Sis-161-19.18, Fall 1984, injected to rebond delaminated epoxy bonded PCC overlay.

12. Walters Road OC Br. #2-149, 2-Sis-5-R44.31, Fall 1984, flood treatment.

13. Louie Rd. OC Br. #2-137, 2-Sis-5-R31.18, Fall 1984, flood treatment.

Future Research

HMWM has been used successfully to re-bond delaminations in three-inch thick low slump PCC concrete overlays. This type of work has been done on the Big Bend Bridge, No. 19-122R, 03-Pla-80-R65.0, and on the Lost River Bridge, No. 2-59, 02-Sis-161-19.18. Big Bend Bridge utilized a portland cement grout bond coat and the Lost River Bridge had an epoxy bond coat. The Big Bend Bridge was treated by flood coating but the Lost River Bridge required holes to be drilled through to the bond line and the HMWM resin was injected. Both applications were considered successful.

Future research is required into applications on vertical surfaces or overhangs. Research has been initiated into evaluating vacuum assisted injection, pressure injection, and reconstruction of pavement slabs in situ.

HMWM monomer has also been used for rehabilitating PCC bridge decks prior to overlaying with AC or epoxy-bonded PCC overlays. The purpose was to toughen the substrate surface and provide a clean, sound bond surface. These applications appear to be successful.

THIN BONDED OVERLAYS

Background Information

An increasing number of portland cement concrete pavements are reaching a condition which requires major rehabilitation. Typically, the corrective strategy has been to 1) subseal with portland cement grout to restore slab support, grind the surface to restore riding quality after repairing localized failures, and install edge drains to prevent further faulting by removal of water present at the base interface, or 2) resurface with asphalt or portland cement concrete and install edge drains. Recent developments include cracking and seating the existing PCC slabs prior to overlaying with AC.

Two major problems associated with deteriorated PCC pavement and bridges are spalls and surface attrition. Spall repairs are addressed elsewhere in this report. Thin bonded overlays may be used to improve ride quality, increase load carrying capacity, and reduce the attack from water and road salts.

Conventional three to four inch thick PCC, AC, or modified PCC overlays may require corrective work to shoulders, median barriers, guardrails, and drainage structures. Problems are also encountered with the dead load added to the bridge structures and clearance reductions under overhead structures. These problems can usually be ignored if the overlay thickness does not exceed one inch.

A literature search and contact with other agencies revealed a number of overlay strategies which had either been adopted or were being used experimentally. Included were high density, low slump PCC for thin (two to four inch) bonded overlays, butadiene styrene latex modified PCC, epoxy bonded PCC, epoxy concrete, MMA polymer concrete and polyester-styrene polymer concrete.

California's experience with high density PCC overlays bonded with portland cement grout has been documented in Caltrans Transportation Laboratory report, "California's Thin Bonded PCC Overlay," published in June 1983 (5). Pavement overlays constructed in 1982 using magnesium phosphate, MMA and

polyester-styrene concrete are discussed in Caltrans Transportation Laboratory report, "Experimental Overlays Utilizing Magnesium Phosphate, Methyl Methacrylate and Polyester-Styrene", to be published during 1986.

Recent work on latex-modified PCC, polyester-styrene concrete and HMWM concrete are discussed in this report.

Preliminary Thin Bonded Overlay Research

Interstate 80 through the Sierra Nevada has severe faulting and surface attrition problems. The pavement structural section is generally adequate, but the concrete has suffered from tire chain wear and freeze-thaw damage. Extremely thin polymer overlays were considered to improve the ride and increase the surface durability of the pavement.

The first studies considered materials which had been previously proposed for spall repairs such as magnesium phosphate concrete, latex-modified PCC, MMA concrete, and polyester concrete.

Experimental overlays with these materials were placed outside at TransLab on a fully cured concrete slab. These experimental overlays were six inch x 60 inch x 3/8 inch. Surface preparation varied from none to aggressive sandblasting. The bonding strength tested by two-inch core direct pull-off tests indicated that all the materials proved to be satisfactory if the surface had been adequately sandblasted, but failed if the PCC base was not abrasively prepared.

A pilot study was initiated consisting of a field trial of promising materials to be used as thin pavement overlays to be placed in freezing and thawing environments. The test area selected was at the 5000-ft elevation on I-80 on the No. 3 (truck climbing) lane. The construction date was September 19, 1979.

Caltrans purchased the materials and furnished the labor for placing the materials. Each company furnished technical assistance. To complete the

installation in one day, a 30-ft-long (two 15-ft slabs), 12-ft-wide test section was proposed for each product.

The companies and products involved were:

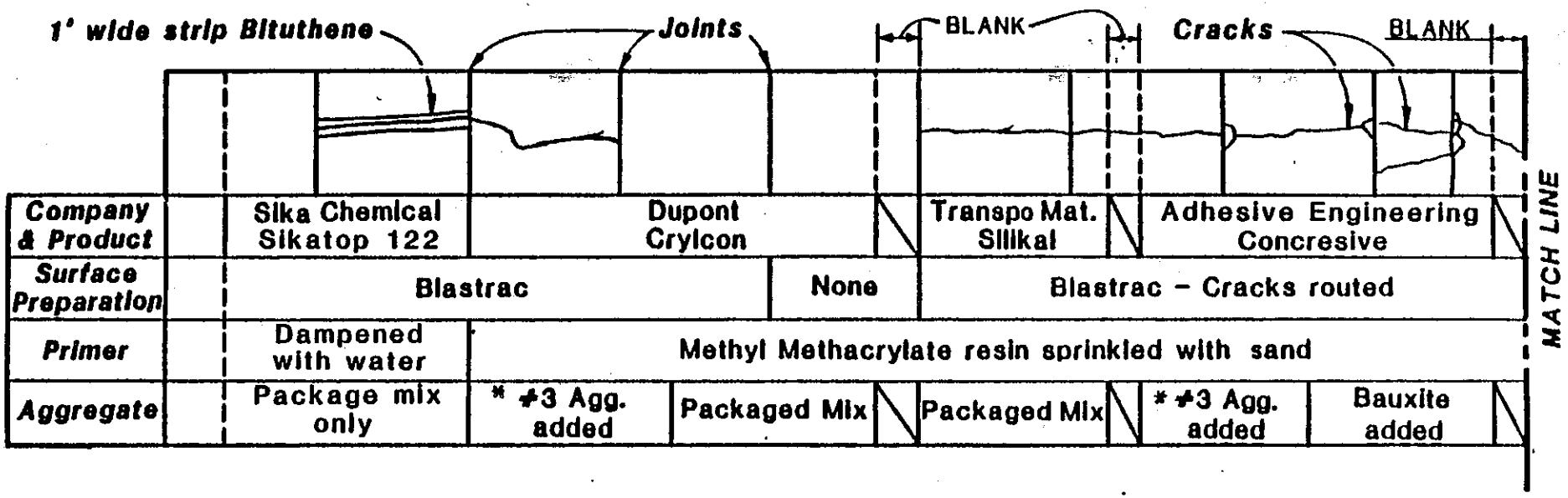
Magnesium Phosphate Concrete-Set 45 - Dry Mix Products
Latex Modified Concrete-Sikatop 122 - Sika Chemical
Polyester-Styrene Resin-Polylite 32-300 - Reichhold Chemical
Methyl Methacrylate Concrete - Crylcon - DuPont
Methyl Methacrylate Concrete - Silikal - Transportation Materials
Methyl Methacrylate Concrete - Concresive - Adhesive Engineering

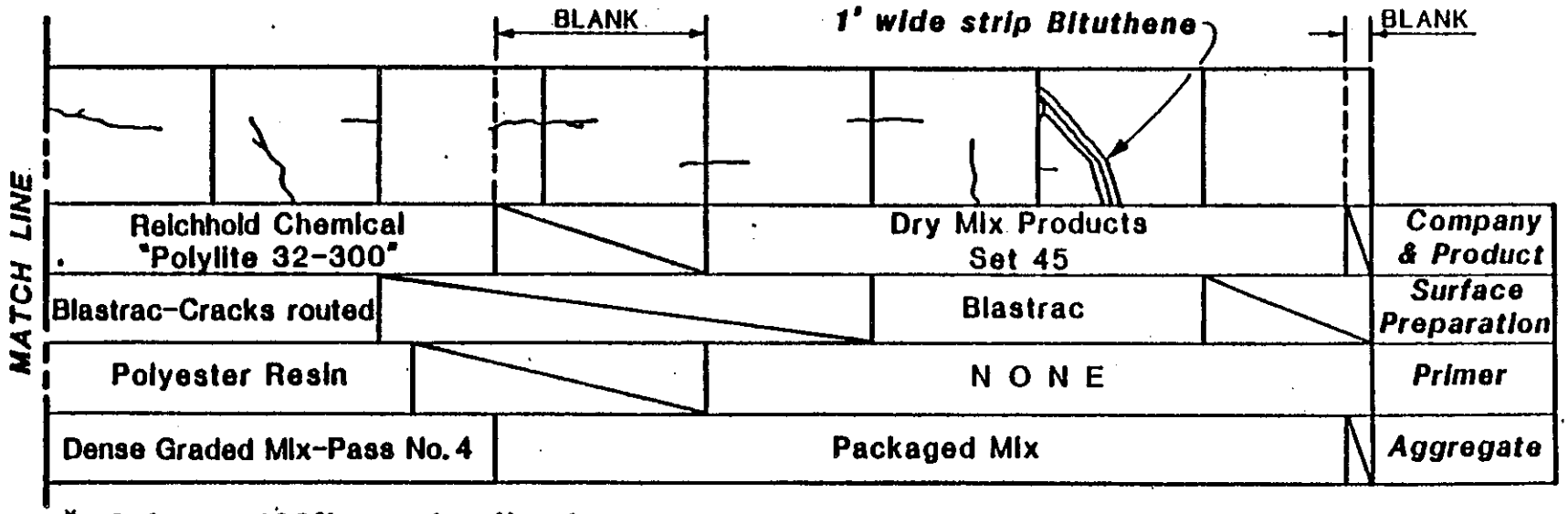
Figure 15 shows the layout of the individual sections as actually constructed.

The manufacturers of the "Blastrac" steel shot abrasive blast machine (Wheelabrator-Frye) offered the use of their machine for cleaning the surface. The Blastrac is electrically powered and cleans by throwing steel shot abrasive onto the surface. It has a shot recovery system and vacuums the dust and residue, providing a relatively dust-free environment. The amount of cleaning and concrete removal can be adjusted by controlling the forward speed of the machine.

Some delays were encountered in getting the construction started. One delay was caused by the large amount of handwork involved in preparing existing longitudinal cracks for filling with polymer concrete. Another delay was due to a problem with the electric generator needed to power the Blastrac. Figures 16 and 17 show the surface preparation using the Blastrac. It was approximately noon by the time the first area had been cleaned so the overlay construction could begin. The Blastrac provided a very clean and rough surface texture. This steel shot blasting is considered preferable to sandblasting for concrete surface preparation for overlays.

The original design thickness for all overlay materials was an average of 3/8 inch. The existing PCC pavement had rutting due to the tire chain abrasion of approximately 1/2 inch depth. The screed rails consisted of 1/4 inch thick flat metal strips to provide a minimum of 1/4 inch overlay thickness. Screeding was done with an aluminum two x four inch board. Due to construction problems, the actual thickness of Set 45 was approximately 1/2 inch and the Silikal was up to one inch in thickness.





*#3 Agg. - 100% passing No. 4

I-80 EXPERIMENTAL OVERLAY
PLACER COUNTY PM 51.80-51.86 APPROX.
Eastbound Truck Lane - 9/19/79

Fig. 15

The Sikatop 122 by Sika was the first to be placed since it had the slowest strength gain. Sikatop 122 is an acrylic copolymer latex modified portland cement based material. The material was mixed in a mortar mixer and placed according to the manufacturer's instruction. The mixing and placing operations went smoothly with no problems and were completed with the application of a resin based curing compound (Figure 18).

The three methyl methacrylate concretes were placed next. Although treatment of the cracks slowed placement, there were no particular problems with mixing or placing these overlay materials. Figures 19 through 23 show the crack preparation and placement of the prime coat and MMA concrete.

The polyester-styrene resin chosen was manufactured by Reichhold Chemicals, Inc. The resin was an isophthalic-based resin with a viscosity near 600 cps. The polyester-styrene concrete mix design was based on previous experience by Oregon DOT (6). The laboratory mixes consisting of dense graded sand and 12% resin could be handled quite readily, but the same proportions in the mortar mixer proved unsatisfactory. To keep the mixer from stalling, additional resin had to be added, making a total of 16-18% resin by weight of the aggregate. The workability and placing were acceptable, but the high resin content resulted in a slick surface. The polyester-styrene was placed rather late in the day and the temperature was dropping noticeably. This delayed the setting of the resin to about two hours. It had originally been designed to set in approximately one hour at 72°F. Figure 24 shows the placement of the polyester styrene concrete.

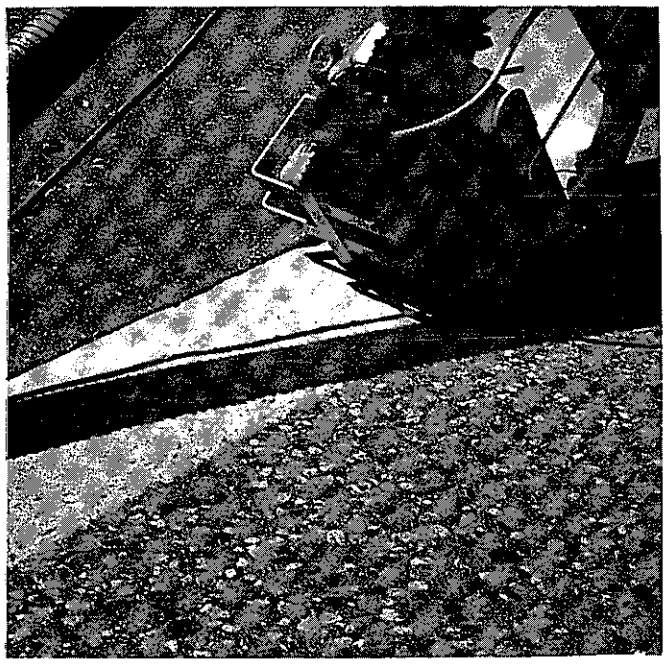


Figure 16 - Surface preparation utilizing "Blastrac" electric steel shotblasting.

Figure 17 - Steel shotblasting effectively removes surface contaminants.

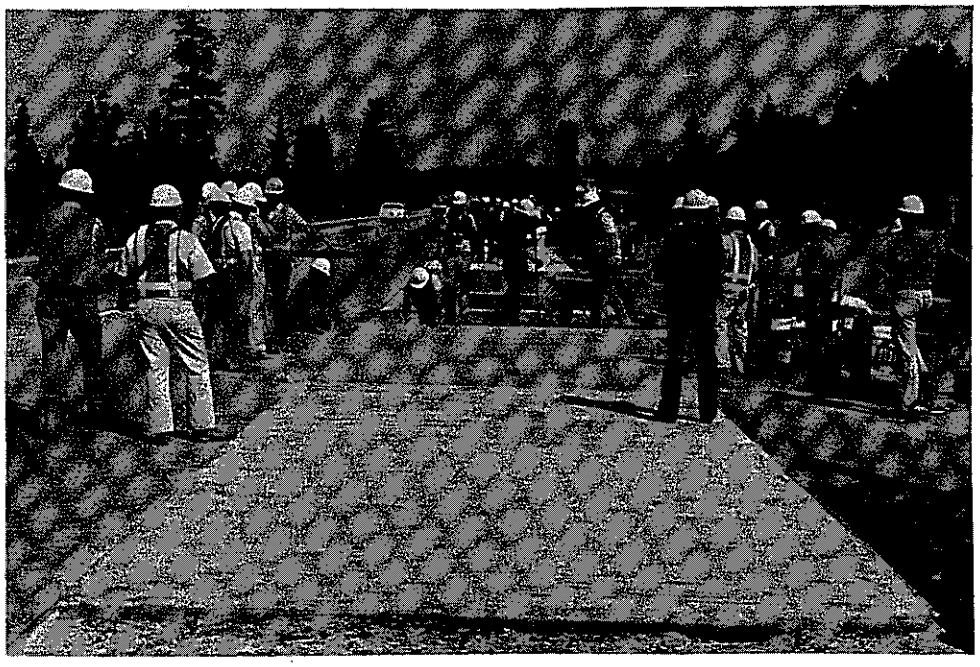


Figure 18 - The placement of Sikatop 122 overlay.

Figure 19 - Chipping and cleaning of pavement cracks prior to overlayment.

Figure 20 - Filling pavement crack with MMA concrete.

Figure 21 - Application of prime coat for MMA overlays.

Figure 22 - Mixing and placing of the methyl methacrylate (MMA) concrete overlays.

Figure 23 - Finished broom texture on the MMA concrete overlays.

Figure 24 - Placement and screeding of the polyester-styrene polymer concrete overlay.

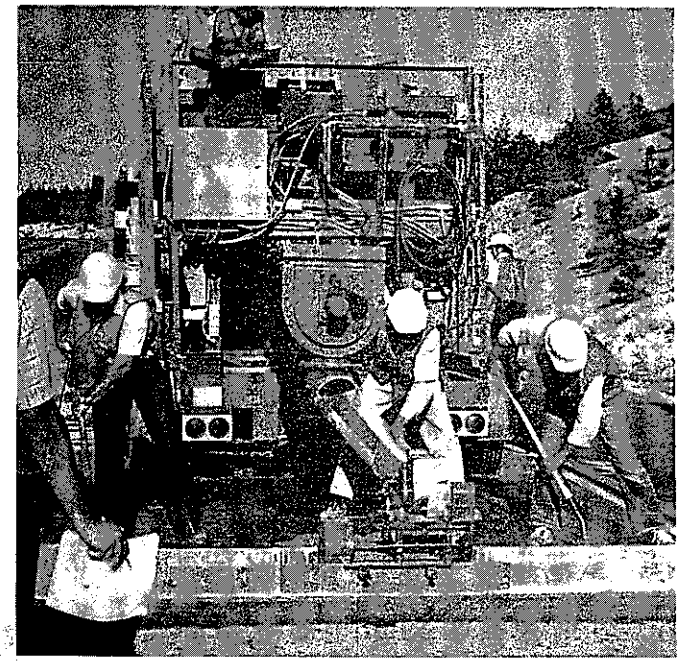


Figure 25 - Continuous mix mobile placing the magnesium phosphate concrete overlay.

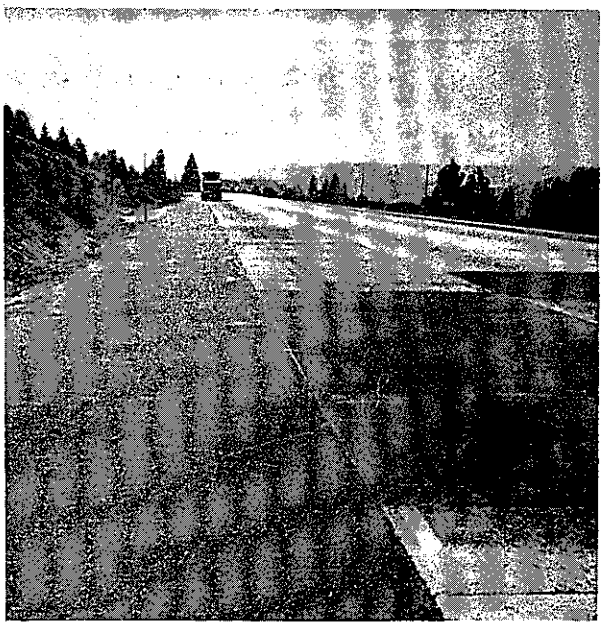


Figure 26 - Overview of the test after placement of overlays.

The magnesium phosphate concrete was mixed in the material supplier's continuous mix machine shown in Figure 25. The placing operation went quite rapidly and smoothly.

All materials were in place before dark but the lane had to be kept closed until the polyester-styrene section hardened. Traffic was allowed on the overlays about 9:00 p.m. Figure 26 shows an overall view of the project.

Cost Analysis

Cost estimates were made on the six types of thin bonded overlays assuming the overlays were placed 3/4 of an inch thick on the 12-foot-wide lanes. Three quarters of an inch thickness was chosen for comparison of systems for use in severe chain wear areas. The cost estimates assumed that there was no bulk discount for the material and that it was batched with drum mixers and placed with a vibratory screed. Expensive continuous mix machines and placement pavers were not considered. All estimates were in cost per lane mile in 1979 dollars.

The shotblast surface preparation was assumed to be $265 per hour including operator costs. The assumed production rate for surface preparation was 1800 sq ft per hour or $9330 per lane mile. Competition and improvements in equipment have decreased the cost of steel shot blasting. A recent 1985 contract bid was less than $1600 per pavement lane mile for a bid quantity of 71,000 square yards.

Construction costs were based on the following assumed labor and equipment needs: 10 laborers at a rate of $30 per hour, four trucks at $35 per hour, and mixers, a vibratory screed and miscellaneous support equipment at $30 per hour.

This gives a total construction cost rate for mixing and placing the material of $470 per hour. The construction rate was assumed to be 1/3 of a mile per eight hour workshift.

COST ESTIMATE IN
DOLLARS PER LANE MILE
(1979 dollars)

Material	Dry Mix Prod. Set 45	Reichhold Chemical Polylite 30-300	Sika Sika Top 122	DuPont Crylcon	Transpor. Material Silikal	Adhesive Eng. Concresive
Material Cost Using Manufacturers' Price Quote	$6,380	$10,090	$26,530	$33,660	$34,650	$36,480
ShotBlast Surface Prep.	9,350	9,350	9,350	9,350	9,350	9,350
Construction Cost	11,280	11,280	11,280	11,280	11,280	11,280
Placement & Material Cost	27,010	30,720	47,160	54,290	55,280	57,110
15% Profit	4,050	4,610	7,070	2,140	8,290	8,570
Total Cost (in 1979 Dollars)	$31,060	$35,330	$54,230	$62,430	$63,570	$65,680

Performance Evaluation

Three weeks following construction, a survey of the test sections was made. The survey revealed some lack of bond in the DuPont MMA, polyester-styrene and magnesium phosphate concrete test sections as shown in Figures 27, 28, and 29. These debonded areas turned out to be areas where the products had been placed beyond the areas prepared by steel shot blasting. The bond failures verified the need for adequate surface preparation. The latex-modified Sikatop 122 concrete also showed signs of spalling at the edges and some delamination. It was felt that traffic had been allowed on this material before it had gained sufficient strength. No claims were ever made that it was a fast strength-gain material. Thus, additional test sections with longer cure times are required to accurately evaluate its potential as an overlay material.

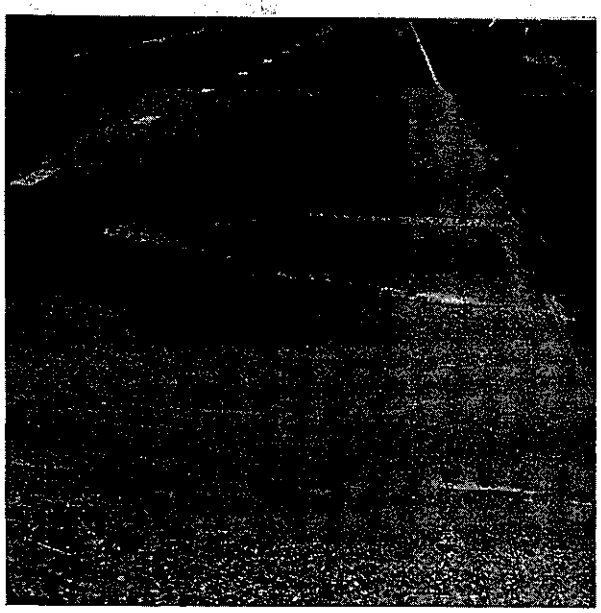


Figure 27 - Loss of material in Set 45 overlay in area without surface preparation.

Figure 28 - Failure of set 45 over Bituthene crack repair. Bituthene is still intact.

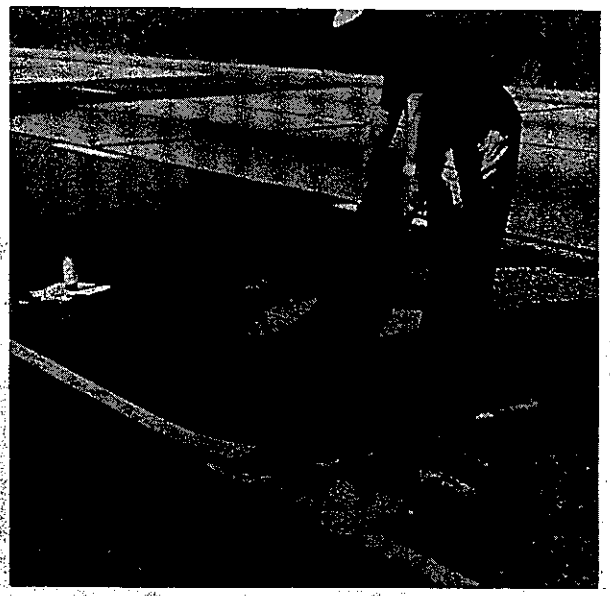


Figure 29 - Showing delamination of polyester-styrene concrete where bonding area was not abrasively cleaned.

Tests to measure skid resistance were made on each section. The results indicated satisfactory skid resistance except for the polyester concrete (due to the high resin content). After three years under traffic, there has been no significant improvement in the polyester concrete skid resistance. The following table shows these skid resistance values.

Skid Resistance of Test Sections - October 1979

Material	SN_{40} Range
PCC Control	36-38
Sika	42-44
DuPont MMA	41-51
Transpo MMA	49-50
Concresive	33-37
Polyester	10-25
PCC Blastrac Cleaned	40-41
Set 45	41-41
PCC Control	30-40

The test section remained open to traffic for two years before any attempt was made to provide repairs and improve riding properties. Most of the unbonded areas surveyed had broken out and all spalled areas were filled with magnesium phosphate concrete.

Tensile Pull-Off Tests

Direct tensile pull-off tests were performed on the field overlays on October 10, 1979. The overlays were 35 days old. The pull-off test consists of coring two inches in diameter through the overlays into the PCC substrate. A bobbin is affixed with epoxy to the overlay surface. After the bobbin is securely affixed, it is lifted vertically until failure. Maximum load at failure and mode of failure are recorded. The average results at three tests per material are presented in the following table.

Tensile Pull-Off Tests
(Overlay Age 35 Days)

Material	Average Ultimate Load (PSI)	Failure Bond
Sika 122	110	Bond
Crylcon MMA	230	PCC/Bond
Silikal MMA	350	PCC
Concresive MMA	450+	PCC & Mat'l. Cohesion
Reichhold Polyester	360	PCC
Set 45	40	Material Cohesion

The tensile pull-off test indicates relative values and may vary greatly depending on the location of the test. Bond failure modes may indicate future delamination problems. For bonding strength, ten psi is adequate but zero psi is not. The overlay is either bonded or it is not.

Shear Strength Tests

Guillotine-type shear strength tests were also performed on the overlay materials. Four-inch core specimens were extracted from each overlay and subjected to 850 freezing and thawing cycles from 0°F to 40°F at an average of eight cycles per 24 hour period. All cores were extracted from areas that had the steel shot blast surface preparation. The shear test results are presented in the following table.

Material	Average Ultimate Load (PSI)	Shear Failure Mode
Sika Top 122	130	Bond
Crylcon MMA	300	Bond
Silikal MMA	500	Concrete/Cohesive
Reichhold Polyester	200	Concrete/Bond
Set 45	200	Cohesive

Adhesive Engineering Concresive was not tested but would be expected to be similar to the other MMA products. All of the materials appear to have adequate bond to a properly prepared surface.

The SikaTop 122 was the only material to show signs of debonding along the side of the core. None of the overlay materials showed any cohesive deterioration due to the freezing and thawing.

Abrasion Resistance Tests

Abrasion resistance tests were performed on cores extracted from the overlays. The overlay materials age at test was 42 days. The abrasion loss results are presented in the following table.

ABRASION LOSS BY CALIFORNIA TEST 550

Date: 10-30-79 Age: 42 Days

Sample	Abrasion Loss (grams)
Sika Chemical Sikatop 122	8
DuPont Crylcon w/aggregate	7
Transportation Materials Silikal	5
Adhesive Engineering Concresive	5
Reichhold Chemical Polylite 32-300	-0-
Dry Mix Products Set 45	16

All materials exhibited acceptable abrasion resistance. Typical abrasion loss for six-sack PCC at 42 days of age is 21 grams.

Summary

The Set 45 and Reichhold polyester concretes were the least expensive alternatives. Bonding properties were satisfactory when applied to a shotblasted surface for all materials, but the latex-modified PCC material, Sika 122, was consistently lowest. Abrasion loss for all the materials was acceptable when compared to a typical abrasion loss for six-sack PCC. The Set 45 had the highest abrasion loss while the polyester had the least.

As a result of these tests, most of the materials were considered candidates for future overlays. The polyester concrete, while possessing excellent durability, was unsatisfactory from a skid resistance standpoint. The polyester resin was modified in the laboratory to obtain a resin with lower viscosity. The lower viscosity resin increased the workability of the mix and resulted in lower resin content and adequate overlay skid resistance.

Further field tests were done under the federally funded research project entitled "Experimental Overlays Utilizing Magnesium Phosphate, Methyl Methacrylate and Polyester-Styrene". One-third mile pavement sections, two lanes wide, were overlaid, approximately 3/4-inch thick, with magnesium phosphate, methyl methacrylate and polyester-styrene concrete in 1982.

Polyester-Styrene Concrete Overlays

Polyester-styrene concrete overlays have several advantages. They are highly abrasion resistant and are impermeable to water and road salts. They may be placed 3/8 to one-inch thick, reducing dead load and clearance problems. Modifications to barrier rails and signing can therefore be avoided. The polyester-styrene concrete is well suited to night work when traffic closures must be short. The resins are also relatively inexpensive and readily available.

Polyester-Styrene Resin

Polyester-styrene is a blend of polyester dissolved in styrene monomer. Generally, the resin is promoted with a metallic drier and has a minimum 1.0% silane coupler added. The silane coupler is necessary to improve the polyester

resin bond to aggregate and to the PCC substrate. The silane coupler specified is an organosilane ester, gamma-methacryloxypropyltrimethoxysilane. The resins are generally initiated with methyl ethyl ketone peroxide (MEKP). The resin gel time is dependent upon temperature, but can be controlled to some extent by varying the initiator (MEKP) percentage.

Polyester-Styrene Concrete

Polyester-styrene concrete can be formulated by adding coarse and fine aggregate to the resin. Well-rounded, hard, low absorption aggregates are generally best suited for optimum workability and performance of polymer concrete. Due to the viscosity of the polyester-styrene resin, a grading that is low in fines is required for efficient mixing. The recommended aggregate gradation for thin overlays is listed in the "Polyester-Styrene Concrete Overlay" specification in the appendix. Also, the workability of the polyester-styrene concrete is directly related to the viscosity of the binder resin. A significant function of the styrene is to decrease the viscosity, which improves the wetting properties of the resin. This permits reducing the resin content to a minimum value. Laboratory tests indicated that the styrene content for optimum workability was 45 to 50% of the resin content. Additional styrene has detrimental effects. Further research is being initiated to evaluate the impact of the styrene content on field performance.

For a 3/4 inch thick overlay, the recommended maximum aggregate size is 3/8 inch pea gravel. Larger aggregates may be useful for large mass applications. The resin and aggregate should be formulated with the highest aggregate loading or the minimum resin content possible for an economical, workable mix. This will reduce the cost, but more importantly, will reduce initial shrinkage and result in an overlay concrete which has a modulus of elasticity and thermal coefficient of expansion closer to that of the PCC substrate. The mixer-blended polyester concretes have a significant advantage over the aggregate "drop-in" methods since the overall resin content of the mixer blended concrete is much lower and can be closely controlled.

Polymerization is an exothermic process. The initial shrinkage will increase as the polymerization rate increases. The slower the resin polymerizes, the lower

the initial shrinkage and the lower the stresses transmitted to the bond interface will be. Shrinkage proceeds fastest during gelling, but may continue for weeks or months. As the resin cures, tensile stresses develop in the resin matrix, aggregates are subjected to compressive stresses, and shear stresses occur at the bond interface.

It is preferable that the long linear chain molecules are formed before substantial chain cross-linking occurs. This will allow most of the shrinkage to occur internally before the resin gains sufficient strength to transmit the stress to the bond line. Testing indicates that approximately one half of the total resin shrinkage occurs while the resin is still a liquid. The accumulated stresses increase proportionally with the resin or overlay thickness. Therefore, the shear stresses transmitted to the bond line are proportionally lower as the thickness of the overlay decreases. Also, internal shrinkage stresses are reduced by increasing the aggregate loading since the binder thickness between filler particles decreases.

A certain amount of closed porosity is helpful in reducing the stresses inherent in initial shrinkage and developed later in thermal stressing. This is mentioned in theory and not to advocate air entrainment of polymer concrete due to possible detrimental chemical reactions since oxygen will inhibit the polymerization. Further research is required into increasing porosity by the use of such things as microballoons. Slow curing times provide sufficient contact time between styrene and atmospheric oxygen or oxygen dissolved in water and may result in defects. In the presence of oxygen, styrene may oxidize forming benzaldehyde and will, therefore, not be available for incorporation into the final matrix (7). The benzaldehyde will then further inhibit proper polymerization. The oxygen inhibition may also be due to steric hinderance caused by oxygen molecules near the double bond reaction site. It is, therefore, important to formulate the resin for a reasonable cure time and to assure proper compaction of polyester-styrene overlays to remove entrapped oxygen in the overlay matrix. To assure proper compaction, a test procedure was developed that requires the use of a nuclear compaction gage in the backscatter mode. The proposed test method is included in the appendix.

The detrimental effect of moisture on polyester-styrene overlay placement cannot be overstated. Besides the dissolved oxygen inhibition, water itself will act as an inhibitor to the polymerization. Caltrans specifies that the aggregate moisture content shall not exceed one-half of the aggregate absorption. The relationship of humidity and its possible inhibition of polymerization on the overlay surface requires further research. The oxygen inhibition that results in surface tackiness is usually not a problem in polyester-styrene overlay systems due to the relatively rapid polymerization rate. The moisture content of the base PCC is also of concern. Water present at the substrate will inhibit the polymerization at the bond interface and act as a bond breaker.

From field experience, it appears that it is beneficial to have the overlay polymerize at the bond interface first - i.e., from the bottom up. If the surface polymerizes first, the initial shrinkage may cause failure at the unpolymerized bond interface. This suggests that the optimum time to place polyester-styrene concrete overlays is after the peak of the daily heating cycle when the substrate is warmer than the surrounding air. This will allow the heat from the existing PCC to polymerize the resin near the bond face prior to polymerization in the remainder of the overlay.

The preparation of the base PCC is of utmost importance. If the base is of poor quality, the polyester-styrene overlay will bond to the poor material and thermal stressing will cause delamination between the poor material and the sound concrete. Even when the base is sound and nonabsorbing, it is important to roughen the surface to increase the bonding effectiveness. Surface preparation by steel shotblasting is strongly recommended. All traces of asphalt should always be removed prior to overlaying. The HMWM has proven to be very effective as a primer for polyester-styrene concrete overlays in laboratory tests and field trials. Thus, the use of HMWM as a primer may eliminate the need for further surface preparation in many cases. The use of HMWM has several advantages. Primer penetration of the substrate is necessary to ensure that the bond interface has a shear strength as high, or higher, than that of the PCC substrate. The low viscosity of the HMWM allows it to penetrate into the microcracks and toughen the PCC surface. This gives a sound, strong surface to bond to and results in a homogeneous strain distribution through the bond interface. Prime coats tested in order of

increasing performance and, unfortunately cost, are isophthalic polyester, vinyl esters, fumarates, and HMWM.

The coefficient of thermal expansion of polyester resin is significantly greater than that of portland cement concrete. The coefficient of thermal expansion in California for PCC is generally near 7.5×10^{-6} inch/inch/°F while the polyester-styrene concrete is typically 12×10^{-6} inch/inch/°F. Any temperature change different from the temperature that the resin cured at will result in high internal stresses which will be transmitted to the bond interface. Shrinkage stresses are always tensile in nature. Thermal stressing can be either tensile or compressive. The stresses may offset each other when the temperature is rising but are additive when the temperature is decreasing. This effect can be minimized by using the maximum practical aggregate loading. The higher the aggregate loading, the more closely the thermal coefficient of expansion will resemble that of the aggregate and, therefore, that of the PCC substrate.

The lower the thermal capacity, the greater the susceptibility of the overlay to damage by thermal shock. This means that the thinner the overlay, the more sensitive it is to rapid temperature change. This parameter opposes the need to keep the overlay thin to reduce the stress due to shrinkage or slower temperature changes. Rapid thermal shock should not be significant in highway structures.

The detrimental effect of temperature change becomes more significant with age since organic resins tend to embrittle with time. As polyester resin is subjected to ultraviolet (UV) radiation from the sun and the resin becomes increasingly brittle, the tensile strength and impact resistance may decrease. This implies that the most elastic resin usable at the early stages would be desirable. This further supports the necessity to maximize the aggregate loading and thereby will significantly reduce the detrimental effects of UV radiation by masking the binder with aggregate.

Caltrans has successfully placed polyester-styrene overlays from 3/8 to one inch in thickness. The maximum size aggregate used for the one-inch thick overlays was 1/2 inch maximum. Most of the polyester-styrene concrete overlays have been performing well. Some wear has been observed due to chain abrasion

when the polyester-styrene concrete was not properly compacted during construction. To date, there has been no delamination of polyester-styrene concrete overlays placed on bridge decks.

Field Trials

Beaver and Thompson Creek Bridges

Polyester-styrene concrete overlays were placed on Beaver Creek Bridge (No. 2-81) and Thompson Creek Bridge (No. 2-68), 2-Sis-96, PM 52.48 and 88.26, in the fall of 1983. These bridges are PCC T-beam construction with an approximate 10% cross slope and both are on curves. The AADT for these bridges is between 500-600. The resin chosen for the primer and concrete binder was a promoted wax-free isophthalic polyester-styrene copolymer with 1.0% silane coupler added. The viscosity of the resin was approximately 200 cps. The aggregate used was Lone Star dry bagged aggregate from Monterey, California. The aggregate grading specified is included in the Polyester-Styrene Concrete Overlay Specification in the appendix. The mix design was one part fine aggregate and one part coarse aggregate (3/8 inch max) with 10.5% polyester-styrene by weight of aggregate. The unit weight was determined to be 137 pounds per cubic foot.

Methyl ethyl ketone peroxide (MEKP) is generally used to catalyze this system. A blend of 75% MEKP and 25% cumene hydroperoxide (CHP) was used to retard the set time. This lowered the peak exotherm and reduced initial shrinkage. The slower set time results in a concrete with a lower modulus of elasticity. Laboratory tests indicate that if the material sets too rapidly, it will tend to debond due to excessive shrinkage.

The PCC surface preparation was done by gasoline powered steel shotblasting equipment. This is a preferred method of surface preparation over sandblasting. It provides a more uniform rough texture and is environmentally desirable because the fines are removed with a vacuum.

Prior to placing the overlay, the prepared surface was primed with a coat of the same resin that was used as the binder in the concrete. The prime coat was

allowed to polymerize before placing the overlay. Laboratory tests indicated that the overlay bonded much better if the polyester resin prime coat was allowed to polymerize before placing the overlay concrete. The overlay grade was controlled by a vibratory strike-off screed placed on screed rails. The overlay thickness varied from 1/2 to three inches in localized areas. Some hand finishing was required to seal the surface and to aid compaction. The vibration on the screed was inadequate to provide optimum compaction. The vibratory strike-off screed was a gasoline engine driven shaft with eccentric weights. However, the eccentric weights were not installed and the vibratory effort was mainly due to shaft wobble on bad bearings. The resulting compactive effort was considered marginal at best and the need to specify and monitor compaction was quite evident. The density test using a nuclear compaction gage was later developed to prevent similar problems on future construction. Laboratory tests are listed for the following physical properties for the polyester-styrene concrete by California Test 551:

Set time @ 75°F - 70 minutes

Compressive strength of 2-inch cubes

3 hour -	400 psi
4 hour -	525 psi
6 hour -	3200 psi
24 hour -	6680 psi
48 hour -	7000 psi

Flexure strength

24 hour -	1940 psi

Modulus of Elasticity

24 hour -	1.67×10^6 psi

The specification in the appendix has been modified since this contract, but the binder resin specification is similar to the resin specified for this contract.

Adequate transverse texturing was obtained using an embossing roller device 16 inches wide with 1/8-inch deep sharp flanges, 1/8-inch wide at 3/4-inch spacings. The texture was rough and pleasing to the eye. Although the vibratory compaction was poor, both overlays are performing well with no sign of surface wear or delamination.

Beegum and Hayfork Creek Bridges

The Beegum Creek Bridge (No. 06-57, 2-Sha-36-PM 11.9) and the Hayfork Creek Bridge (No. 05-07, 2-Tri-36-PM 38.4) were overlaid with polyester-styrene concrete in July 1984. The Hayfork Creek Bridge is the larger of the two structures and is in a more severe environment. The ADT is only about 200. It is located at 3400 ft elevation on a minus 6.9% grade and a 1280-foot radius curve. The bridge is a three-span continuous T-beam with a 7-inch concrete deck. The Hayfork Creek Bridge is being monitored to evaluate the effectiveness of polyester-styrene concrete overlays in protecting the reinforcing steel from corrosion and to determine possible reduction in future maintenance costs.

The surface was prepared using an electric powered steel shotblast machine. This prepared a 10-inch wide track and traveled at approximately 700 lineal ft per hour. The deck preparation was considered very satisfactory. The prime coat used was a low viscosity HMWM at a coverage rate of 100 sq ft per gal. Laboratory tests and field trials indicated that this is preferred over the isophthalic polyester bond coat. The superelevation of the deck was approximately 8%. Even combined with the near 7% grade, there were no flow problems encountered with the polyester-styrene concrete. The overlay was placed using an air driven vibratory strike-off screed. Wood screed rails were placed to obtain a 3/4-inch thick uniform deck plane. The polymer concrete was mixed in two 9.5 cu ft drum mixers. The mix design complies with the specification for "Polyester-Styrene Concrete Overlay" contained in the appendix. The catalyst used was 2/3 MEKP and 1/3 CHP to slow the initial set time because of the +95°F placement temperature.

A condition survey in November 1984 indicated that both overlays were sound with no delamination and no signs of surface wear.

Figure 30 - Application of HMWM prime coat for polyester-styrene concrete overlay.

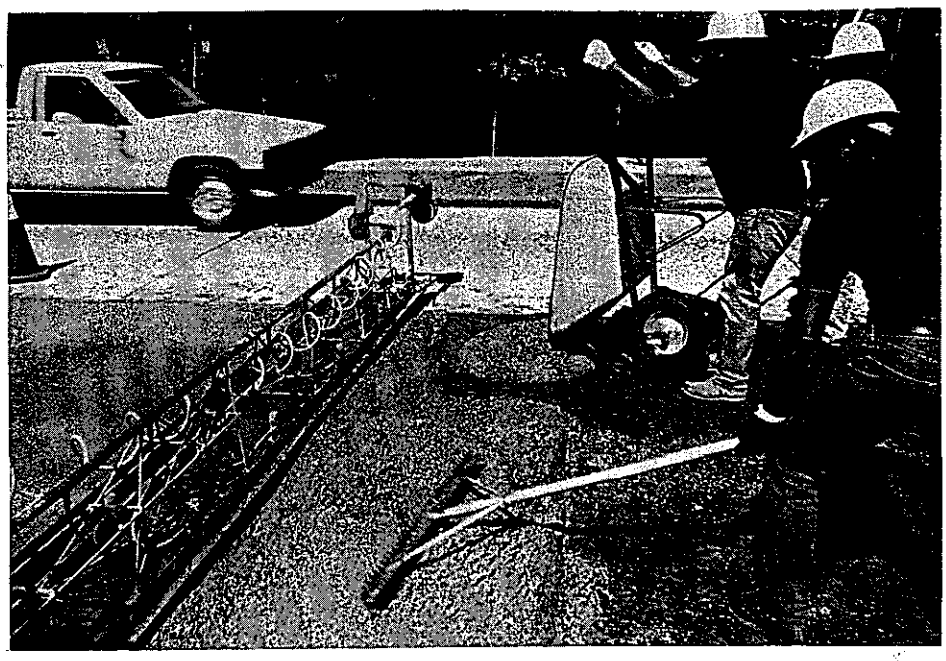


Figure 31 - Placing 1" thick polyester-styrene concrete. Note air driven vibratory screed.

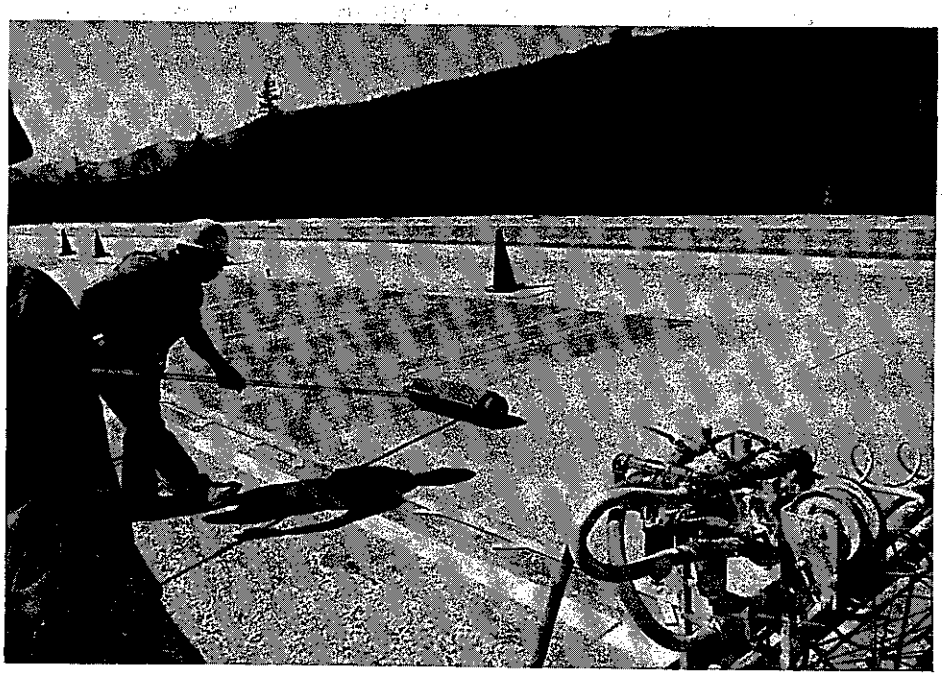


Figure 32 - Texturing of polyester-styrene concrete overlay. Aggressive surface texture has been eliminated on future contracts due to excessive surface tearing.

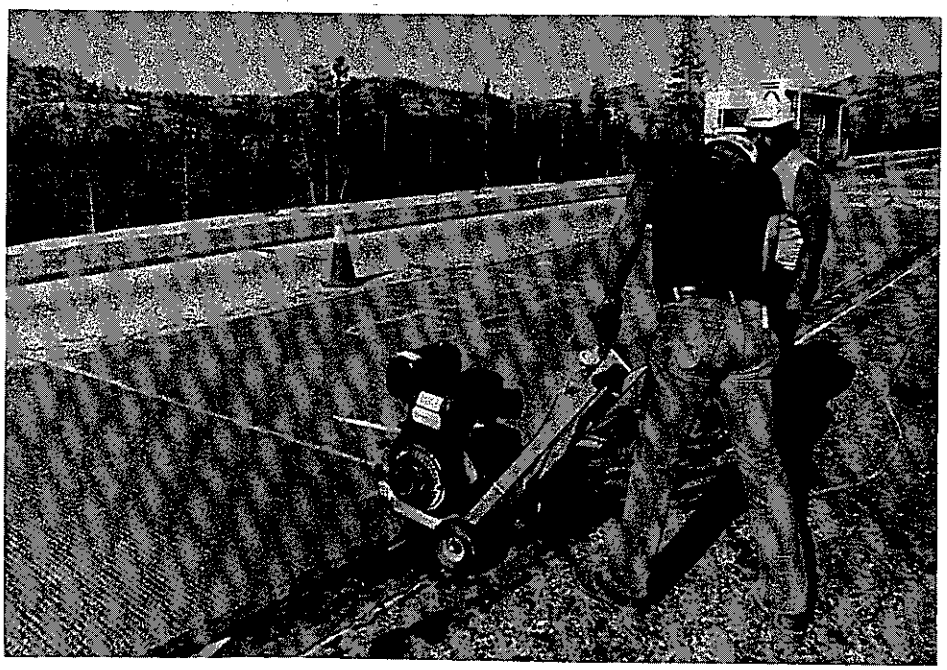


Figure 33 - Sawcutting polyester-styrene concrete overlay. Should be done within four hours of placement.

Texturing was accomplished by using the roller device used on the Thompson and Beaver Creek Bridges. The texturing was very irregular and damaged the overlay surface. This illustrated the need to avoid disturbing the polyester-styrene concrete after it has been compacted. If the surface is torn it will not heal. Texturing of the polyester-styrene overlays has been eliminated from future contracts. Skid tests indicated that texturing was not required. We do recommend a coarse sand grit to be broadcast on the overlay surface directly after finishing. A solvent, such as acetone, is required to clean up equipment used with polyester-styrene concrete. Photographs of the construction process of a test overlay near Soda Springs on I-80 during 1984 are included as Figures 30 to 33.

The polyester-styrene concrete overlays placed in California prior to mid-1985 are listed below with contract numbers and locations.

1. 1979 - Whitmore Grade - Test overlay; 03-Pla-80, highway test slabs
2. 1982 - Soda Springs - 03-217324; 03-Nev-80-0.9/1.9, 1/3 mile highway overlay
3. 1983 - Thompson Creek Bridge - 02-144004; 02-Sis-96-52.48, bridge overlay
4. 1983 - Beaver Creek Bridge - 02-144004; 02-Sis-96-88.26, bridge overlay
5. 1984 - Hayfork Creek Bridge - 02-201004; 02-Tri-36-38.37, bridge overlay
6. 1984 - Beegum Creek Bridge - 02-201004; 02-Sha-36-11.9, bridge overlay
7. 1984 - Carson River Bridge - 10-252504; 10-Alp-89-13.3, bridge widening and overlay
8. 1984 - Soda Springs - 03-299204; 03-Nev-80-0.9, highway overlay
9. 1985 - Whitmore - 03-255334; 03-Pla-80-49.1/52.8, highway overlay

Polyester-Styrene Resin Seal Coat

Several test sections have been placed using the polyester-styrene resin as a binder for stone chip to increase skid resistance. The technology is similar in design to asphaltic seal coats. The stone chip cannot be disturbed while the resin is polymerizing since permanent damage to the molecular chain formation will occur. Rolling of the stone chip is not required and could be very detrimental. Polyester resin seal coats have several advantages over asphaltic seal coats. The polyester resin polymerizes rapidly, thereby reducing traffic delays, and the resin will reduce the surface permeability. Test sections have been placed in Sacramento, Rio Vista, Fresno and San Jose. The first contract work was done during the spring of 1985 at Pacheco Pass on Route 152 under Contract 04-113724. Additional evaluation is required but initial testing looks promising. A sufficient demand for this technology has been expressed throughout the state to justify further immediate testing and research. The proposed specifications for polyester seal coat are included in the appendix.

Future Research

Future research on polyester-styrene concrete overlays includes steel reinforcing for thin polyester overlays, effectiveness in preventing bridge deck steel corrosion, new texturing techniques, determining the structural value of overlays and research into polyester bonded seal coats. Equipment such as continuous mix machines and bridge paving machines should be well suited for placing polyester-styrene concrete. Further evaluation of mixing and placing equipment is required.

High Molecular Weight Methacrylate Concrete Overlays

Polymer concrete overlays have been placed utilizing HMWM monomer as the binder. A different monomer than the crack sealing monomer may be specified for use as a concrete binder. A low resin modulus of elasticity is more important for concrete than desired for crack sealing. A material with higher flexibility will reduce the stress transmitted to the bond line or PCC substrate since some of the environmental stresses will be accommodated in the resin

matrix. This will reduce the probability of delamination and the likelihood of cracking. The recommended compressive modulus of elasticity for HMWM concrete used for patching or overlays should be less than 1.0×10^6 psi.

HMWM Monomer

The HMWM monomer concrete has several advantages over other polymer patching and overlay materials. The low resin viscosity and good wetting characteristics yield a very workable concrete mixture at a low resin content. The lower resin percentage required for a workable mix will reduce initial shrinkage stresses and increase the compatibility with the PCC substrate. The monomer has a low initial curing shrinkage compared with other organic resins. The resin properties and excellent wetting characteristics provide excellent bonding to aggregate, PCC and steel. This reduces the required surface preparation to a minimum.

HMWM Concrete

Typical HMWM concrete properties determined by California Test 551 methods are:

Working Time (min)		30
Time to Traffic (min)		120
Compressive Strength (psi)	2 hr.	4500
	3 hr	5500
	6 hr	6000
	24 hr	6700
Abrasion Loss (grams)	24 hr	7
Flexural Strength (psi)	24 hr	2155
Modulus of Elasticity (psi)	24 hr	1.71×10^6
Bond to SSD and Dry PCC	Greater than the flexural strength of PCC	
Absorption (%)		0.5

Figure 34 - Laboratory test showing 3" HMWM overlay causing shear failure of PCC substrate due to environmental thermal stressing.

HMWM concrete has been used for spall repairs, bridge header material, and for bridge deck overlays. Care must be taken not to exceed a two to three-inch overlay thickness since laboratory tests indicate that environmental stress may fail the PCC substrate approximately one to two inches below the bond line. In a laboratory test, a three-inch thick HMWM overlay one ft wide x eight ft long was cast over a large fully cured PCC slab. The PCC slab had a steel trowel finish without significant macrotexture. The surface was lightly sandblasted. The resin used as the concrete binder for this test was the higher modulus of elasticity monomer used for crack sealing.

The overlay was placed over an uncured HMWM prime coat and polymerized within two hours. No initial delamination was detected. Delaminations were detected after approximately one month of natural thermal cycling. The overlay was broken off to show the delamination occurred approximately one and a half inches down into the PCC substrate. The overlay and bond face were still intact. A picture of the failure is presented in Figure 34. This indicates the resin actually toughened the top inch of the PCC surface and that the overlay bond strength is far superior to the tensile, flexural or shear strength of the PCC. The results are not expected to be nearly as dramatic using a lower modulus monomer but excessive overlay thicknesses must be still avoided.

Field Trials

Two bridges were overlaid with HMWM polymer concrete by contract change order on Contract No. 02-135004. The bridges overlaid were the Rte 89-5 Separation (Br. No. 2-127E) and Elk Creek Bridge (Br. No. 2-46). The Elk Creek Bridge was overlaid on June 14, 1984. The bridge is a 32 foot wide, single-span T-beam bridge 45 ft long. The overlay was placed 3/4 inch thick with a "Texas" vibratory strike-off screed. A prime coat of (crack sealing) higher "E" type HMWM was applied at 85 SF/gal. The lower modulus HMWM concrete was mixed in 3 cu ft concrete mixers. The mix design consisted of 12% pozzolan, 44% pea gravel, 44% sand and 6% HMWM monomer by weight of aggregate. The monomer was catalyzed with cobalt napthanate and benzoyl peroxide. The mix was workable and easy to place. The concrete polymerized in 30 minutes and was opened to traffic in one hour. The air temperature was near 70°F and the deck temperature was nearly 100°F. One half of the bridge

was sandblasted while the other was just lightly swept. The bonding was adequate in both cases with no sign of delamination to date. Both lanes were overlaid during a single work shift. Specifications for HMWM concrete overlays are included in the appendix. Photographs of the construction procedure are shown in Figure 35 to 37.

The Route 89/5 Separation was overlaid with the same equipment and in the same manner. Three types of HMWM monomers with different degrees of flexibility were tested. The resin concrete modulus of elasticities were 4.5×10^6, 2.2×10^6 and 0.6×10^6. Initial evaluation included coring for bond line shear strength and installation of wear indicators. The overlays will be evaluated over the next several years. The contractor rinsed the drum mixer with water after every third batch to keep the material from adhering to the mixer. This incorporated water into the HMWM concrete and seriously reduced the resin matrix strength resulting in raveling of the overlay surface at every batch immediately after this water wash. The lower modulus of elasticity resins were more adversely affected by the addition of water. The overall surface is spotty and resulted in a very rough ride. The high modulus of elasticity HMWM concrete has extensive cracking throughout the overlay. HMWM concrete overlays may not be applicable where extreme temperature variations may cause cracking or PCC shear failure.

There have been several other structural repairs using HMWM concrete. It has performed well for spall repair, as a header material, and for filling shallow dips and tapers. HMWM is well suited for thin patches or tapers since it has a high tensile strength and high bonding capacity.

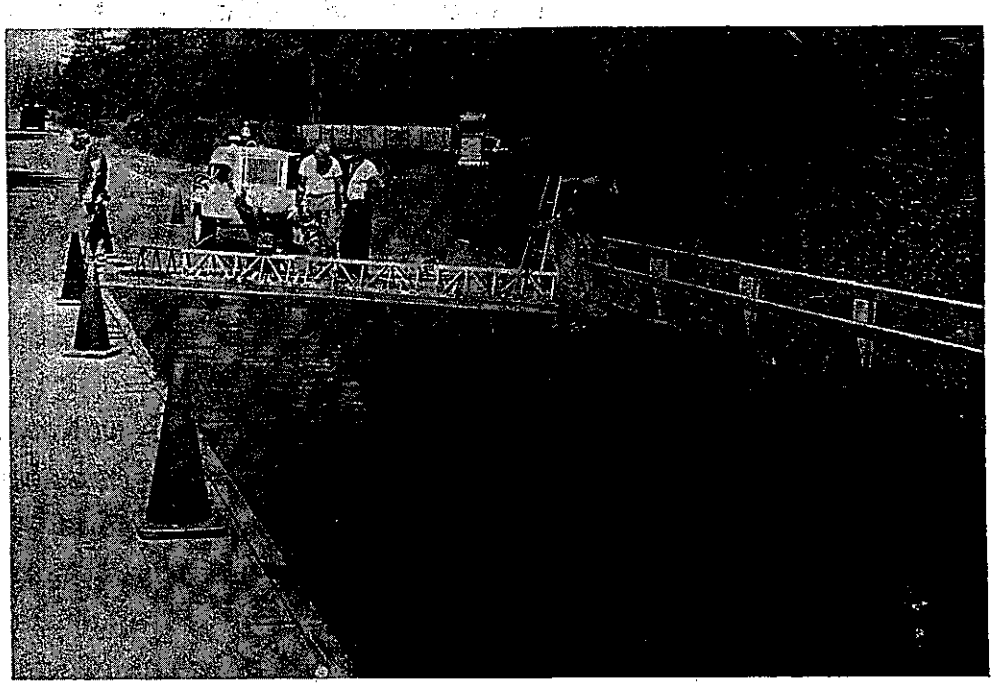


Figure 35 - Application of HMWM prime coat.

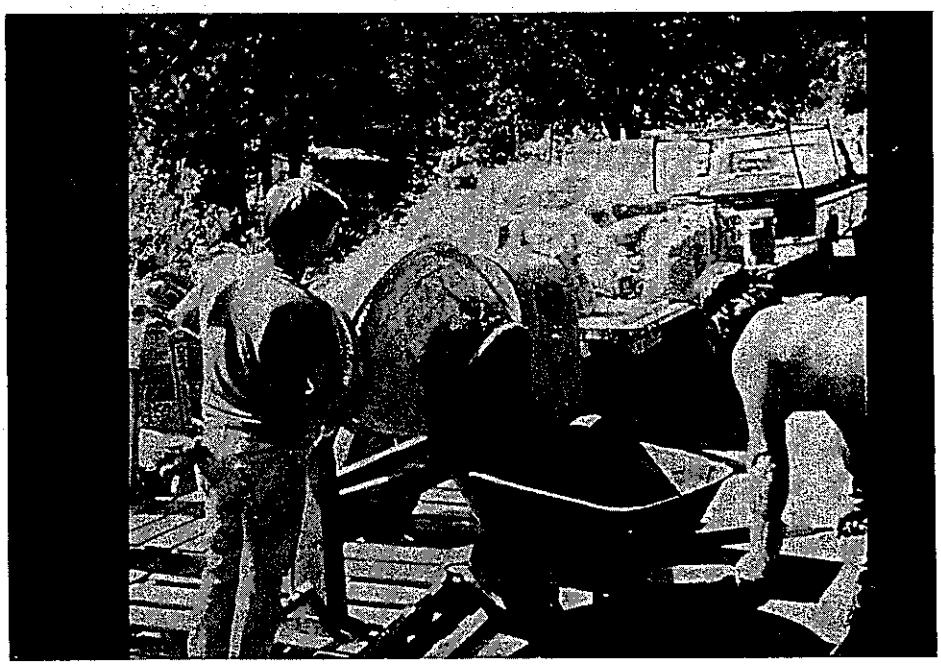


Figure 36 - The HMWM concrete was mixed in common drum concrete mixers.

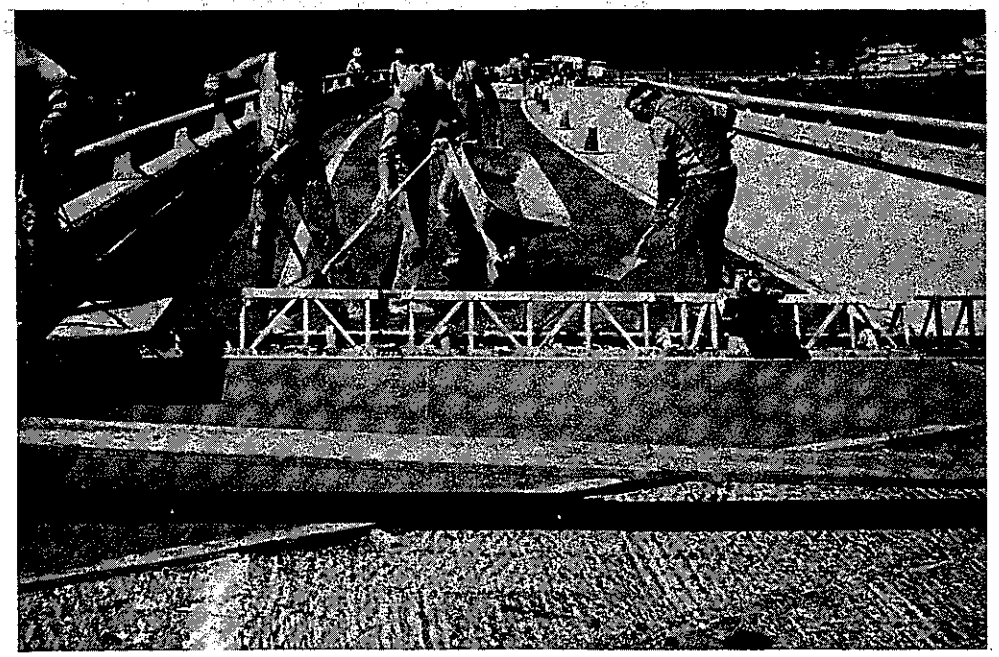


Figure 37 - Vibratory screed used to finish 1" thick HMWM concrete overlay.

Latex-Modified Portland Cement Concrete Overlays

Latex-modified portland cement concrete can be considered an organic modified inorganic material. Latex-modified PCC generally refers to styrene butadiene latex copolymer added to PCC. The polymerization of the styrene butadiene latex and the hydration of the portland cement occur simultaneously.

The latex-modified concrete (LMC) is not considered a rapid setting material. It must be limited to use where normal Type II portland cement concrete could be used. The styrene butadiene latex is supplied as an emulsion which is approximately 50% water. It is added to a conventional portland cement concrete as the gaging water. This must be included when determining liquid/cement or water/cement ratios.

Mixing, placing, curing, and set time are similar to those for portland cement concrete. The color of LMC is typically light blue gray. The resulting tacky surface can be difficult to finish. Tool cleaning is generally more difficult than with PCC.

Typical physical properties of portland cement concrete and latex-modified portland cement concrete are listed in Table III. Test results are for 8-sack PCC, 3/8 inch maximum aggregate, with liquid to cement ratios near 0.34. Latex admixture was added at a rate of approximately 3.5 gallons per sack of cement.

The test results indicate that 24-hour compressive and flexural strengths are somewhat improved by the addition of the latex admixture. Ultimate compressive strength, bonding to PCC, abrasion resistance and modulus of elasticity appear to be similar to the control PCC.

One of the advertised benefits of adding styrene butadiene admixture is a decrease in permeability of the concrete. The absorption of LMC is less than that of PCC. This lower permeability may be of value when overlaying bridge decks to protect reinforcing steel from road salts. The LMC may be an effective chloride barrier provided that it does not crack or delaminate.

Table III

Typical Properties of Latex-Modified PCC

Test	PCC	Latex-Modified PCC
Compression (psi)		
1 day	2400	3700
7 days	5100	5140
28 days	6600	6600
Flexural (psi)		
1 day	300	480
7 days	740	675
28 days	820	680
Bonding to PCC (psi)		
to Dry PCC		
7 days	370	470
to SSD-PCC		
7 days	360	340
Abrasion loss (grams)		
7 days	13	13
Modulus of Elasticity		
($x10^6$)psi		
28 days	5.0	5.0
Absorption		
7 days	5%	2%

*All tests were done in accordance to California Test 551 methods.

Additional laboratory testing was performed to test the bonding properties of LMC. An area one ft x eight ft of a PCC slab was overlaid with three inches of latex-modified concrete at the Transportation Laboratory in December 1982. Four ft of the existing PCC bond surface was prepared by chipping with a bush hammer. The remaining four ft was abraded using an electric steel shotblast machine. Both are considered to be aggressive methods of surface preparation. A bond coat of the latex modified grout was worked into the surface as the overlay was placed. Thermal cycles were simulated using heat lamps which produced a maximum surface temperature of approximately 100°F. The surface was then allowed to cool to approximately 50°F. A total of 14 cycles were completed in a 22-day period. Corner delaminations appeared after two cycles (three days) in the section with the chipped bond surface. Corner delaminations were detected on the shotblasted section after four cycles (seven days). Progressive delaminations were noted in conjunction with stress cracking at approximately 18-inch intervals.

Dial indicators were installed at each end of the test slab prior to testing, to measure both the horizontal and vertical deflection caused by the thermal gradients. The maximum relative horizontal end movement due to heat expansion was 0.002 inch and 0.010 inch for the shotblasted and chipped bond surfaces, respectively. The maximum relative vertical curling deflections were 0.0005 inch for the shotblasted bond surface, and 0.0013 inch for the chipped bond surface. It appears that the steel shotblaster provided a better bonding surface than the chipping hammer. This type of progressive bonding failure is typical of the failure experienced when overlaying with PCC and a cement grout bond coat.

Field Trial

Cranbrake Road Undercrossing

Latex modified concrete overlays were placed on Cranbrake Road Undercrossing (Br #57-588 R/L) and the 8/84 Separation (Br 57-604 R/L) on Interstate 80 in San Diego County during the spring of 1985. Each structure is a three-span reinforced concrete slab.

The existing PCC surfaces were prepared by grinding and steel shotblasting. The surfaces were then blown clean using a high pressure air hose. The extent of deterioration, after the preparation, ranged from no apparent signs of delamination or cracking to severe spalling. The eastbound structure of Cranbrake Road Undercrossing was spalled enough to expose the top mat of reinforcing steel. One hole completely penetrated the bridge deck. This hole was formed up by wiring a piece of plywood under the deck to the reinforcing steel. The exposed steel showed signs of corrosion and was cleaned by abrasive blasting prior to overlaying. The shotblasting surface preparation provided up to 1/2 inch relief.

The mix design recommended by Dow Chemical representatives was as follows:

portland cement	658 lb
sand (SSD)	1490 lb
gravel (SSD)	1375 lb
latex emulsion	206 lb
additional water	123 lb

The mix water to cement ratio was 0.31. The solids content of the latex emulsion was 48% as reported by the manufacturer. The liquid to cement ratio, including the liquid from the latex emulsion, was 0.50.

A test batch was mixed in the laboratory in a drum type mixer.

Compressive strengths of the laboratory mix were 3740 psi and 4230 psi at four and seven days, respectively. Dow Chemical representatives proposed a mix design and procedure for the bond coat slurry mix as follows:

Cement	100 lb
Sand	250 lb
Latex emulsion	30 lb

Water was added (15 to 20 lb) until a creamy "pancake batter" consistency was obtained. This was mixed with a shovel and then scrubbed onto the deck with a broom.

This prepared surface was kept moist until the overlay was placed. The westbound overlay design thickness was 0.20 ft. Styrofoam was used as a bulkhead at each end of the bridge to produce a uniform joint. The latex-modified concrete was mixed with continuous mix, auger-type mobile mixers. The average deck surface temperature was 75°F. A Bidwell power strike-off screed was equipped with a vibrating pan (which operated at 2500 to 6000 vibrations per minute) and a burlap drag. Since the screed was unable to cover the entire width of the deck, two spud vibrators were used to consolidate the outside edges. At the time of discharge, the color and workability of the latex concrete resembled that of conventional portland cement concrete. It acquired a greenish tint and a thin latex surface skin after approximately five minutes. Materials testing personnel conducted slump, air and unit weight tests on the first mobile mixer load. The results were as follows:

air	2.8%
slump	7 1/2 inches
unit weight	143.3 lb/ft^3

A Kelly ball was also used to measure penetration, but inconsistent values were obtained from consecutive tests. This may be due to the stickiness of the latex-modified concrete.

The tining consisted of transverse grooves approximately 1/4 inch deep and 3/8 inch apart. Wear indicators were installed in the plastic concrete in each wheel line for future evaluations.

Dow representatives stated from past experience that if no material adhered to your palm when lightly touching the overlay surface, it was ready for curing. The overlay was then cured by applying a white plastic film over damp burlap. A total of 19.8 cubic yards of latex-modified concrete was placed on this westbound structure.

The equipment was then moved to the eastbound structure of Cranbrake Road Undercrossing. This overlay was designed to be approximately 0.10 foot in thickness. The overlay procedure was identical to that of the westbound

structure. Special attention was required to prevent water from accumulating in potholes in the substrate. A total of 15.4 cubic yards of latex concrete was placed on this structure. The two structures at the Route 8/84 Separation were overlaid with latex-modified concrete the following night. The Transportation Laboratory plans to continue to monitor the performance of these overlays.

District 11 Structures personnel reported to TransLab that the latex-modified concrete overlays had experienced shrinkage cracking. On the Cranbrake Road structures, one 6-foot long crack was reported in the westbound overlay, but no signs of cracking were noted in the eastbound overlay. The two structures at the Route 8/84 Separation experienced extensive cracking. The surfaces of these structures were subsequently sealed with a latex slurry mix in an attempt to heal the cracks.

The shrinkage cracking in the latex overlays described above may be associated with the utilization of the continuous mixer. Shrinkage cracking has been observed in the past with conventional portland cement concrete due to the short mixing time, approximately six to nine seconds, resulting in false setting. The false setting due to the gypsum in the cement will result in early slump loss and extensive shrinkage cracking. California does not generally allow the use of continuous mobile-mix concrete mixers for structural concrete work due to this short mixing time.

SUBSEALING WITH SILICONE FOAM TO PREVENT PAVEMENT FAULTING

California pavements are generally nonreinforced PCC slabs with skewed joints at spacings of 12, 15, 13 and 14 ft and repeat. Most older pavements do not contain edge drain systems. TransLab has done extensive research on the use of silicone resin foam for subsealing these pavements. This technology has consistently prevented faulting of PCC pavement slabs tested in the laboratory. The silicone foam that was tested during this research was General Electric SCS4400 foam. The silicone is a two-component resin which, when mixed in a 1:1 ratio, reacts to form a silicone foam. The foam cures in about 10 to 20 minutes and has a volume expansion ratio of approximately 4:1.

Four field installations have been placed in California. The first test section was placed in 1981 on southbound I-5 near Williams. The first section to be placed by contract was a two-mile section constructed in 1983 on I-5 near Yreka - Contract No. 02-144704.

Two additional test installations have been constructed by contract change order. One project constructed during July 1984 under Contract No. 10-278104, was near Los Banos in Merced County on Interstate 5. This project incorporates one mile in the northbound and southbound No. 2 lanes between PM 29 and 30. The most recent project was located in Kern County near Mettler on Interstate 5. The northbound and southbound No. 2 lanes between PM 23.8 and 25.5 were subsealed under Contract No. 06-245003. It is also planned to evaluate one additional project scheduled for construction during 1986 on Interstate 101 south of San Francisco. Photographs of the installation procedure are shown in Figures 38 through 41.

The laboratory testing and the future monitoring of the test sections will be included under a federally funded research program, Experimental Project No. 9, "Pavement Rehabilitation Techniques." The silicone foam subsealing will be evaluated and compared to the current method of cement grout subsealing and installing edge drains. The test sections include a silicone subsealing only section and a silicone subsealing with edge drains section. The control sections include a section without rehabilitation and a section subsealed using cement grout with edge drains.

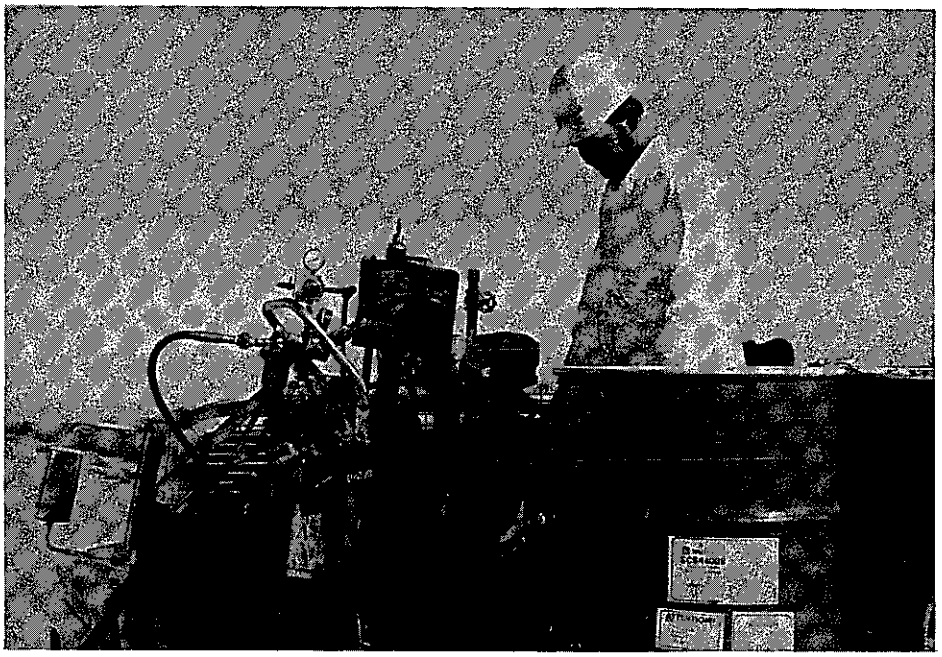


Fig. 38 - Binks dual component pneumatic pump used for silicone foam injection.

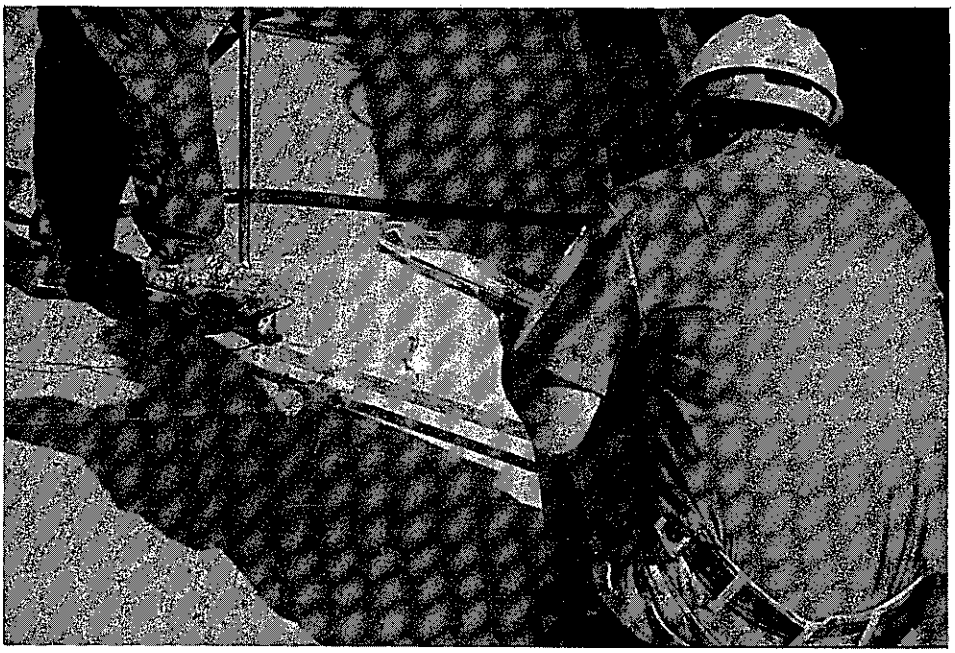


Fig. 39 - Delivery nozzle used to inject silicone. Faulting gauge was used to measure differential lift of slabs during injection.

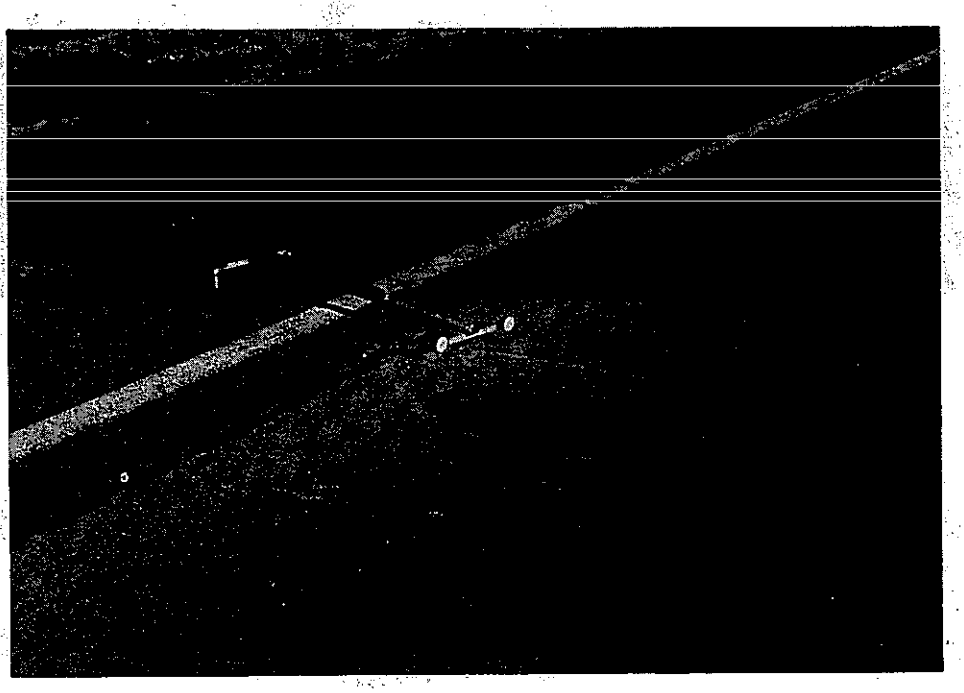


Fig. 40 - A modified Benkleman Beam was used to measure slab lift in relationship to the shoulder.

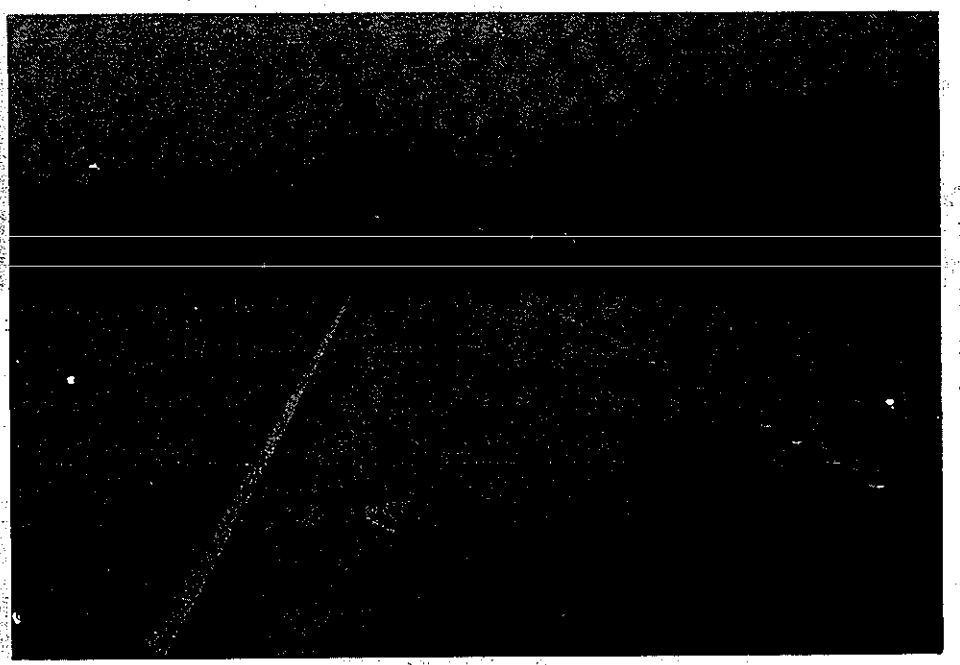


Fig. 41 - After the silicone foam had cured, the excess material was scraped off the slabs with a shovel.

The field installations demonstrated that the construction process was not difficult and the preliminary results indicate that the foam has been effective in mitigating faulting.

The optimum silicone injection quantity has been determined to be between 1.0 and 1.3 gallons of material per joint per 12-foot lane width. This was determined from laboratory tests and from experience on these earlier jobs.

Silicone foam subsealing is currently recommended to mitigate pavement faulting where the installation of edge drains is not practical. The specification for Pavement Subsealing (Silicone Foam) is included in the appendix.

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9. NCHRP Synthesis of Highway Practice 45, Rapid Setting Materials for Patching of Concrete.

10. The Use of Polymer Concrete for Bridge Deck Repairs on the Major Deegan Expressway, Federal Highway Administration, Report No. FHWA-RD-75-513.

Note: Pages 96 thru 109 have been deleted.

APPENDIX I

TEST RESULTS OF PCC PATCHING MATERIALS

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:    ACD CONSTRUCTION GROUT      DATE OF LAST TEST: 10/84
                FORMULA
              87.3%  ACD GROUT
               12.7%  WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      50

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:
      24-HOURS:  4165
      28-DAYS:

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    430
          COMPRESSIVE DRY            3055
          COMPRESSIVE WET
          BOND TO DRY PCC            330
          BOND TO SSD PCC            435
          ABRASION LOSS (GRAMS)      26
               E (X10 6)             2.58
          SPECIFIC GRAVITY;          2.15
          UNIT WEIGHT (#/CF)        134.2
          ABSORPTION (%):            5.2
    COMMENTS:

    MANUFACTURER: ACD INTERNATIONAL  2110 POWERS FERRY ROAD N.W.
ATLANTA
```

```
          ****************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ****************************************
TRADE NAME:  ACME ELASTOMERIC CONCRETE     DATE OF LAST TEST: 5 /84
               FORMULA
             28.08%  PART "A"
             3.73%  PART "B"
             68.19%  PART "C"
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  2085
       28-DAYS:   2095

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2070
           COMPRESSIVE DRY            2465
           COMPRESSIVE WET
           BOND TO DRY PCC            1080
           BOND TO SSD PCC            480
           ABRASION LOSS (GRAMS)
                E (X10 6)             .04
           SPECIFIC GRAVITY;          1.8
           UNIT WEIGHT (#/CF)         112.4
           ABSORPTION (%):            .9
     COMMENTS:                        -PART A RESIN--PART B HARDENER--PART C AGG. =
BLACK ELASTIC MTL.GOOEY TO WORK-STICKY
    MANUFACTURER: ACME HIGHWAY PRODUCTS CORP.  168 CREEKSIDE DR.  AMHERST N.Y. 141
716-691-3001
```

```
          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:          ALLCRETE 5            DATE OF LAST TEST: 1 /81
               FORMULA
             83.3% ALLCRETE 5
               16.7% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   85
        3-HOURS:  90
       24-HOURS:  2080
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:
*
    MANUFACTURER: CONCRETE PRODUCTS INC.  P.O. BOX 1011  WOODLAND CA 95695
916-666-1808
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          ALL CRETE 20          DATE OF LAST TEST: 1 /81
               FORMULA
            85.7% ALLCRETE 20
               14.3% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      200

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   65
        3-HOURS:  55
       24-HOURS:  2380
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    295
           COMPRESSIVE DRY            1845
           COMPRESSIVE WET
           BOND TO DRY PCC            370
           BOND TO SSD PCC            170
           ABRASION LOSS (GRAMS)      60
                E (X10 6)
           SPECIFIC GRAVITY;          2.20
           UNIT WEIGHT (#/CF)        137.2
           ABSORPTION (%):            5.44
     COMMENTS:
*
    MANUFACTURER: CONCRETE PRODUCTS INC.  P.O. BOX 1011  WOODLAND CA 95695
916-666-1808
```

```
        ******************************************
        *   S U M M A R Y   O F   R E S U L T S   *
        ******************************************
TRADE NAME:          AMERCRETE              DATE OF LAST TEST: 8 /82
               FORMULA
              POWDER 78.54%
              LIQUID 21.46%
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   500
        3-HOURS:  870
       24-HOURS:  3150
       28-DAYS:   8825

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    480
           COMPRESSIVE DRY            3050
           COMPRESSIVE WET            2255
           BOND TO DRY PCC            540
           BOND TO SSD PCC            490
           ABRASION LOSS (GRAMS)      30
                E (X10 6)             1.56
           SPECIFIC GRAVITY;          2.1
           UNIT WEIGHT (#/CF)         131.2
           ABSORPTION (%):            7.92
     COMMENTS:    SAMPLE RCD 8-10-82 FROM 5603 ARROW HIGHWAY--MONTCLAIR CA 91763
*
    MANUFACTURER: AMERICAN SLATE PRODUCTS INC. 1990 N. CALIFORNIA BLVD. #830
WALNUT CREEK CA 94596  415-932-7044
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:AMERICAN ANCHOR ALL P.A.CEMENT  DATE OF LAST TEST: 5 /84
                FORMULA
            81.78% ANCHOR ALL
                18.22% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   3015
        3-HOURS:  3025
       24-HOURS:  4610
       28-DAYS:   6950

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:
                      -LIGHT GREY COLOR
    MANUFACTURER: *- AMERICAN CEMENT PRODUCTS, 3012 ATWATER,
*   BURLINGAME, CALIF, 94010
```

```
          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:     AMERICAN 100 NS GROUT       DATE OF LAST TEST: 6 /84
                 FORMULA
             61.97% N.S. GROUT
                6.97% WATER
             31.06% PEA GRAVEL
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  7775
       28-DAYS:   11175

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    735
           COMPRESSIVE DRY            6235
           COMPRESSIVE WET
           BOND TO DRY PCC            510
           BOND TO SSD PCC            345
           ABRASION LOSS (GRAMS)
                E (X10 6)             4.44
           SPECIFIC GRAVITY;          2.21
           UNIT WEIGHT (#/CF)         137.9
           ABSORPTION (%):            3.8
     COMMENTS:    *
POURED OR DRY PACK
    MANUFACTURER: AMERICAN CEMENT INDUSTRIES   BURLINGAME CA.
415-697-7493
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:    AMERICAN HIGHWAY PATCH      DATE OF LAST TEST: 6 /84
                FORMULA
              87.6%  HWY PATCH
               12.4%  WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  3090
       24-HOURS:  6075
       28-DAYS:   10830

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    475
           COMPRESSIVE DRY            3995
           COMPRESSIVE WET
           BOND TO DRY PCC            320
           BOND TO SSD PCC            455
           ABRASION LOSS (GRAMS)      20
                E (X10 6)             3.52
           SPECIFIC GRAVITY;          2.20
           UNIT WEIGHT (#/CF)        137.3
           ABSORPTION (%):            2.9
     COMMENTS:    MEDIUM GREY COLOR--STICKY
CONSISTANCY TO FINISH---NO ODOR
    MANUFACTURER: * - AMERICAN CEMENT PRODUCT, 3012 ATWATER, BURLINGAME,
*    CALIF, 94010
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          ANKER TITE            DATE OF LAST TEST: 2 /84
               FORMULA
             30.6% ANKER TITE
             40.0% PEA GRAVEL
              21.6% SAND PCC
                7.8% WATER
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:     200

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   4150
        3-HOURS:  4250
       24-HOURS:  4815
       28-DAYS:   9025

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    395
           COMPRESSIVE DRY            2305
           COMPRESSIVE WET
           BOND TO DRY PCC            225
           BOND TO SSD PCC            310
           ABRASION LOSS (GRAMS)      37
                E (X10 6)             3.3
           SPECIFIC GRAVITY;          2.05
           UNIT WEIGHT (#/CF)         127.6
           ABSORPTION (%):            9.4
     COMMENTS:    MATERIAL SOAKED IN WATER, CHALKS

    MANUFACTURER: AMERICAN SLATE PRODUCTS INC.    WALNUT CREEK CA
415-415-932-7044
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S - *
*****************************************
TRADE NAME:            AZ SLICK              DATE OF LAST TEST: 10/80
                 FORMULA
                89.3% AZ SLICK
                 10.7% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:      100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   2520
        3-HOURS:  2440
       24-HOURS:  2550
       28-DAYS:   2610

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY          635
           COMPRESSIVE WET
           BOND TO DRY PCC          130
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    MATERIAL BREAKS DOWN IN WATER

    MANUFACTURER: AZ SLICK INC.  2212 SOUTH PRIEST ROAD  UNIT 106
TEMPE ARIZONA 85282     602-968-4521
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:  BONSAL FAST SETTING CEMENT    DATE OF LAST TEST: 5 /85
                FORMULA
            82.29% FAST SET CEMENT
                10.76% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  175
       24-HOURS:  2815
       28-DAYS:   6650

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)    22
                E (X10 6)
           SPECIFIC GRAVITY:
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
    MANUFACTURER: W.R. BONSAL CO.    111 N. VINELAND AVE
CITY OF INDUSTRY CA 91746     818-333-2217
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          BOSTIK 276            DATE OF LAST TEST: 12/82
               FORMULA
               18.4% LIQUID
               81.6% POWDER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   2550
        3-HOURS:  4390
       24-HOURS:  5310
       28-DAYS:   11000

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    465
           COMPRESSIVE DRY            3910
           COMPRESSIVE WET            3845
           BOND TO DRY PCC            490
           BOND TO SSD PCC            115
           ABRASION LOSS (GRAMS)      21
                E (X10 6)             3.88
           SPECIFIC GRAVITY;          2.25
           UNIT WEIGHT (#/CF)        140.2
           ABSORPTION (%):            3.45
     COMMENTS:
*
    MANUFACTURER: EMHART CHEMICAL GROUP---THE UPCO COMPANY
500 WEAT 17TH  LONG BEACH CA 90813
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:      BURKE ACRYLIC PATCH        DATE OF LAST TEST: 2 /84
                 FORMULA
             82.78% BURKE ACRYLIC
                 17.22% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   710
        3-HOURS:  810
       24-HOURS:  3640
       28-DAYS:   10675

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:                        ---EASY FINISHING--PUTTY LIKE

    MANUFACTURER: THE BURKE CO.  PHILLIP WESTFALL--PRODUCT MGR.  SAN MATEO
415-349-7600
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          BURKE HWY 928          DATE OF LAST TEST: 10/84
                FORMULA
               90.56% HWY 928
                9.44% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   3380
        3-HOURS:  4825
       24-HOURS:  7045
       28-DAYS:   10550

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    545
           COMPRESSIVE DRY            5315
           COMPRESSIVE WET            4005
           BOND TO DRY PCC            545
           BOND TO SSD PCC            475
           ABRASION LOSS (GRAMS)      21
                E (X10 6)             4.08
           SPECIFIC GRAVITY;          2.40
           UNIT WEIGHT (#/CF)        149.9
           ABSORPTION (%):            2.0
     COMMENTS:    *
*
    MANUFACTURER: THE BURKE CO.  PHILLIP WESTFALL--PRODUCT MGR.
SAN MATEO   415-349-7600
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          CHEM-CON              DATE OF LAST TEST: 2 /82
              FORMULA
             92.3% CHEM-CON
               7.7% WATER
                  *
                  *
                  *
                  *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   5300
        3-HOURS:  8230
       24-HOURS:  9930
       28-DAYS:

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE
          COMPRESSIVE DRY          5850
          COMPRESSIVE WET          6360
          BOND TO DRY PCC          910
          BOND TO SSD PCC
          ABRASION LOSS (GRAMS)    22
               E (X10 6)
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *
*
    MANUFACTURER: DRY MIX PRODUCTS CO.   P.O. BOX 730  ROSEVILLE CA 95661
916-783-8168
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        CONCRESSIVE 1463          DATE OF LAST TEST: 3 /83
              FORMULA
          12.83% LIQUID PART A
          4.15% LIQUID PART 'B
            83.02%  AE AGG.
                  *
                  *
                  *

RECOMMENDED MAXIMUM EXTENSION:       100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  19400
       28-DAYS:   22700

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2445
           COMPRESSIVE DRY            16470
           COMPRESSIVE WET
           BOND TO DRY PCC            920
           BOND TO SSD PCC            885
           ABRASION LOSS (GRAMS)
                E (X10 6)             4.23
           SPECIFIC GRAVITY;          2.23
           UNIT WEIGHT (#/CF)        139.0
           ABSORPTION (%):            0.1
     COMMENTS:    SEMI TRANSLUCENT---AGG. FINE SILICA
*
    MANUFACTURER: ADHESIVE ENGINEERING    SAN CARLOS CA
415-592-7900
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        CONCRESSIVE 1470          DATE OF LAST TEST: 5 /84
                 FORMULA
             5.63% PART A RESIN
            2.92% PART B HARDNER
                91.45% AGG
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  10155
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    3735
           COMPRESSIVE DRY            11055
           COMPRESSIVE WET
           BOND TO DRY PCC            1340
           BOND TO SSD PCC            355
           ABRASION LOSS (GRAMS)      1
                E (X10 6)             1.89
           SPECIFIC GRAVITY;          2.09
           UNIT WEIGHT (#/CF)         130.25
           ABSORPTION (%):            .3
     COMMENTS:    DRY GREY COLOR.              TROWELABLE. AN EPOXY MORTAR SYSTEM

    MANUFACTURER: ADHESIVE ENGINEERING CO.     SAN CARLOS CA
415-592-7900
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        CONCRESSIVE 2020          DATE OF LAST TEST: 8 /82
                 FORMULA
             6.50% COMPONENT A.
             93.5%  B 2010/2020
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  7845
       24-HOURS:  8990
       28-DAYS:   9000

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  2400
           COMPRESSIVE DRY          10960
           COMPRESSIVE WET
           BOND TO DRY PCC          715
           BOND TO SSD PCC          565
           ABRASION LOSS (GRAMS)    1
                E (X10 6)           3.99
           SPECIFIC GRAVITY;        2.28
           UNIT WEIGHT (#/CF)       142.5
           ABSORPTION (%):          .2
     COMMENTS:

    MANUFACTURER: ADHESIVE ENGINEERING CO.    1411 INDUSTRIAL RD.
SAN CARLOS CA 94070   415-5992-7900
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        CONCRESSIVE 2075          DATE OF LAST TEST: 12/84
                 FORMULA
                 44% PCC SAND
                44% PEA GRAVEL
                 12% FLY ASH
                   8% RESIN
                  1% CO NAP
                    4% CHP

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  11910
       28-DAYS:   14200

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2365
           COMPRESSIVE DRY            11565
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC            1115
           ABRASION LOSS (GRAMS)      7
                E (X10 6)             4.1
           SPECIFIC GRAVITY;          2.33
           UNIT WEIGHT (#/CF)        145.6
           ABSORPTION (%):            0.0
     COMMENTS:    HIGH MOLECULAR WEIGHT METHACRYLATE BASED
MUST FORMULATE
    MANUFACTURER: ADHESIVE ENGINEERING     SAN CARLOS CA
415-592-7900
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:     CONCRETE PRODUCTS 747        DATE OF LAST TEST: 11/81
                 FORMULA
                  89.04% 747
                 10.96% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:      100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  9020
       28-DAYS:   15790

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  635
           COMPRESSIVE DRY          6995
           COMPRESSIVE WET
           BOND TO DRY PCC          205
           BOND TO SSD PCC          390
           ABRASION LOSS (GRAMS)    20
                E (X10 6)
           SPECIFIC GRAVITY;        2.19
           UNIT WEIGHT (#/CF)       136.7
           ABSORPTION (%):          6
     COMMENTS:

    MANUFACTURER: CONCRETE PRODUCTS INC.  P.O. BOX 1011  WOODLAND CA  95695
916-666 3633
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:      CONKRYL QUICK PATCH        DATE OF LAST TEST: 9 /84
                 FORMULA
               61.95% POWDER
                7.25% LIQUID
              30.80% PEA GRAVEL
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  9140
       24-HOURS:  10365
       28-DAYS:   10390

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    1855
           COMPRESSIVE DRY            9270
           COMPRESSIVE WET
           BOND TO DRY PCC            965
           BOND TO SSD PCC            590
           ABRASION LOSS (GRAMS)      8
                E (X10 6)             2.66
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    ACRYLIC BASED PATCHING COMPOUND--MMA TYPE
*
    MANUFACTURER: PACIFIC HORIZON SYSTEMS INC.   SUITE 300  1497 MARINE DR.
WEST VANCOUVER B.C. CANADA V7T-188     604-926-6075
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:        CONO/CRETE 101          DATE OF LAST TEST: 4 /81
                FORMULA
             85.7% PART A AGGREGATE
              9.9% PART B LIQUID
              4.4% PART C LIQUID
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  2030
       28-DAYS:   5215

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)    3
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
    MANUFACTURER: CON/CHEM INC.   12301 WILSHIRE BLVD   PO BOX 25577
LOS ANGELES CA 90025    213-820-3621
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        CONO/CRETE 149          DATE OF LAST TEST: 3 /81
                FORMULA
            4.1% PART-A LIQUID
           95.9% PART-B AGGREGATE
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  1980
       24-HOURS:  6725
       28-DAYS:   7490

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    3235
           COMPRESSIVE DRY            9640
           COMPRESSIVE WET
           BOND TO DRY PCC            985
           BOND TO SSD PCC            410
           ABRASION LOSS (GRAMS)      2
                E (X10 6)
           SPECIFIC GRAVITY;          2.04
           UNIT WEIGHT (#/CF)         127.2
           ABSORPTION (%):            .2
     COMMENTS:        GREY COLOR

    MANUFACTURER: CON/CHEM INC.   12301 WILSHIRE BLVD.  P.O. BOX 25577
LOS ANGELES CA  90025    213-820-3621
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        DOW DERAKANE 411          DATE OF LAST TEST: 3 /83
                 FORMULA
              66.67% PCC SAND
             33.33% PEA GRAVEL
              12% DERAKANE 411
                 1.25% MEKP
                0.3% CO NAP
                 0.05% DMA

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2075
           COMPRESSIVE DRY            7622
           COMPRESSIVE WET
           BOND TO DRY PCC            530
           BOND TO SSD PCC            560
           ABRASION LOSS (GRAMS)      3
                E (X10 6)             3.1
           SPECIFIC GRAVITY;          2.23
           UNIT WEIGHT (#/CF)         139.3
           ABSORPTION (%):            .3
     COMMENTS:    VINYL ESTER CONCRETE
*
    MANUFACTURER: DOW CHEM CO.    SAN FRANCISCO CA
415-944-2000
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        DOW DERAKANE X          DATE OF LAST TEST: 3 /83
              FORMULA
            66.67% PCC SAND
           33.33% PEA GRAVEL
               12% RESIN
               1.25% MEKP
              0.3% CO NAP
               0.05% DMA

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
        3-HOURS:
       24-HOURS:  6475
       28-DAYS:   11080

           24 HOUR TESTS  (PSI)
           FLEXURE                    1975
           COMPRESSIVE DRY            7465
           COMPRESSIVE WET
           BOND TO DRY PCC            840
           BOND TO SSD PCC            370
           ABRASION LOSS (GRAMS)      3
                E (X10 6)             2.12
           SPECIFIC GRAVITY;          2.2
           UNIT WEIGHT (#/CF)         137.4
           ABSORPTION:                .3
     COMMENTS:     *
*
    MANUFACTURER: DOW CHEM CO.      SAN FRANCISCO CA
415-944-2000
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:            DURACAL              DATE OF LAST TEST: 10/84.
               FORMULA
              82.76% DURACAL
               17.24% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   3425
        3-HOURS:  3840
       24-HOURS:  7390
       28-DAYS:   12095

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    410
           COMPRESSIVE DRY            4465
           COMPRESSIVE WET            4150
           BOND TO DRY PCC            315
           BOND TO SSD PCC            375
           ABRASION LOSS (GRAMS)      18
                E (X10 6)             2.29
           SPECIFIC GRAVITY;          2.06
           UNIT WEIGHT (#/CF)        128.8
           ABSORPTION (%):            5.3
     COMMENTS:
EXCELLENT FREEZE THAWING RESISTANCE
    MANUFACTURER: UNITED STATES GYPSUM   101 SOUTH WACKER DRIVE
CHICAGO ILL. 60606
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
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TRADE NAME: DURAL FLEXOLITH DATE OF LAST TEST: 8 /34

FORMULA
10.62% PART A
4.63% PART B
84.75% AGGREGATE
*
*
*

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A T E N T A T I V E T E S T S

COMPRESSIVE STRENGTH (PSI)

1-HOUR:	
3-HOURS:	
24-HOURS:	3210
28-DAYS:	3860

24 HOUR TESTS (PSI)-MAXIMUM AGGREGATE EXTENSION

FLEXURE	2540
COMPRESSIVE DRY	4805
COMPRESSIVE WET	
BOND TO DRY PCC	950
BOND TO SSD PCC	60
ABRASION LOSS (GRAMS)	6
E (X10 6)	.55
SPECIFIC GRAVITY;	2.26
UNIT WEIGHT (#/CF)	141.3
ABSORPTION (%):	1.22

COMMENTS:

MANUFACTURER: DURAL INTERNATIONAL CORP. 95 BROOK AVE. DEEK PARK NEW YORK
516-586-1655

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:            EPI-REZ              DATE OF LAST TEST: 2 /84
              FORMULA
           34.84% PEA GRAVEL
           34.84% P.C.C. SAND
          18.57%TYPEIII CEMENT
          6.81%H2O+3.21%EPIREZ
           .49% EPI-CURE(828)
             1.24% DARASET

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  3105
       28-DAYS:   9195

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    450
           COMPRESSIVE DRY            2665
           COMPRESSIVE WET
           BOND TO DRY PCC            465
           BOND TO SSD PCC            395
           ABRASION LOSS (GRAMS)      17
                E (X10 6)             2.14
           SPECIFIC GRAVITY;          2.26
           UNIT WEIGHT (#/CF)         141.1
           ABSORPTION (%):            1.4
     COMMENTS:    EPI-REZ (50840)
L/C=.633
    MANUFACTURER: CELANESE CORP.      502-585-8079
*
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          FAST KRETE            DATE OF LAST TEST: 7 /81
                FORMULA
            76.20% FAST KRETE
                23.4% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   3675
        3-HOURS:  3640
       24-HOURS:  4280
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    415
           COMPRESSIVE DRY            2985
           COMPRESSIVE WET
           BOND TO DRY PCC            280
           BOND TO SSD PCC            80
           ABRASION LOSS (GRAMS)      34
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    CURED MATERIAL DISSOLVES IN WATER

   MANUFACTURER: PACE PRODUCTS INC.   81 ST. & INDIANA
KANSAS CITY  MISSOURI  64132
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          FAST PATCH            DATE OF LAST TEST: 3 /82
              FORMULA
            90.9% FAST PATCH
               9.1% WATER
                  *
                  *
                  *
                  *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   105
        3-HOURS:  160
       24-HOURS:  2200
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    325
           COMPRESSIVE DRY            1695
           COMPRESSIVE WET
           BOND TO DRY PCC            285
           BOND TO SSD PCC            310
           ABRASION LOSS (GRAMS)      29
                E (X10 6)             3.19
           SPECIFIC GRAVITY;          2.52
           UNIT WEIGHT (#/CF)         157.4
           ABSORPTION (%):            4.6
     COMMENTS:    BLACK COLOR

    MANUFACTURER: CHEMTREE CORP.   950 THIRD AVE.   NEW YORK N.Y. 10022
212-759-5709
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:      5 STAR HIGHWAY PATCH        DATE OF LAST TEST: 3 /84
                 FORMULA
                 87.7% 5 STAR
                 12.3% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:       100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   4970
        3-HOURS:  6875
       24-HOURS:  9300
       28-DAYS:   11500

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    790
           COMPRESSIVE DRY            7095
           COMPRESSIVE WET            6160
           BOND TO DRY PCC            420
           BOND TO SSD PCC            295
           ABRASION LOSS (GRAMS)      16
                E (X10 6)             4.3
           SPECIFIC GRAVITY;          2.27
           UNIT WEIGHT (#/CF)        141.5
           ABSORPTION (%):            2.3
     COMMENTS:
*
    MANUFACTURER: K D COLEMAN CO.   SANTA CLARA CA
408-244-8948
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:              FONDU                DATE OF LAST TEST: 1 /81
                FORMULA
            46.7% 3/8"PEA GRAVEL
               25.7% PCC SAND
             19.1% FONDU CEMENT
                 8.5% WATER
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    795
           COMPRESSIVE DRY
           COMPRESSIVE WET            5935
           BOND TO DRY PCC            420
           BOND TO SSD PCC            265
           ABRASION LOSS (GRAMS)      16
                E (X10 6)
           SPECIFIC GRAVITY;          2.33
           UNIT WEIGHT (#/CF)         145.6
           ABSORPTION (%):            4.46
     COMMENTS:    *
*
    MANUFACTURER: LONE STAR LAFARGE INC.     18 KOGER EXCECUTIVE CENTER SUITE 220
NORFOLK VA. 23502      804-461-1600
```

```
          ****************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ****************************************
TRADE NAME:          FS-CEMENT              DATE OF LAST TEST: 10/84
               FORMULA
             87.55% E-8337-1
               12.45% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   2040
        3-HOURS:  3155
       24-HOURS:  3770
       28-DAYS:   5812

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)    23
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
    MANUFACTURER: STAUFFER CHEMICAL CO     WESTPORT CONN 06881
*
```

```
          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:        FS-16 PRE-KRETE          DATE OF LAST TEST: 10/80
                 FORMULA
                 11.1% WATER
               88.9% PRE KRETE
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   1145
        3-HOURS:  1035
       24-HOURS:  1800
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    210
           COMPRESSIVE DRY
           COMPRESSIVE WET            590
           BOND TO DRY PCC            100
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT ($/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
    MANUFACTURER: POCONO FABRICATORS  DIVISION OF PATTERSON-KELLEY CO.
HARSCO CORP.   EAST STROUDSBURG PA 18301
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        HB 9000 GROUT          DATE OF LAST TEST: 6 /84
              FORMULA
          89.68% HB 9000 GROUT
              10.32% WATER
                   *
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  50
      24-HOURS:  6995
      28-DAYS:   11445

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                  720
          COMPRESSIVE DRY
          COMPRESSIVE WET          6945
          BOND TO DRY PCC          145
          BOND TO SSD PCC          30
          ABRASION LOSS (GRAMS)    17
               E (X10 6)           5.2
          SPECIFIC GRAVITY;        2.16
          UNIT WEIGHT (#/CF)       135.1
          ABSORPTION (%):          5.4
    COMMENTS:    NON-SHRINK NON METALLIC GROUT-MEDIUM GREY COLOR

   MANUFACTURER: HUNT PROCESS CO.  12767 EAST IMPERIAL HWY.  P.O. BOX 2111
SANTA FE SPRINGS CA 90670---213-941-0231
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:   HMWM (METHACRYLATE)-400      DATE OF LAST TEST: 3 /84
                FORMULA
               44% PEA GRAVEL
                44% PCC SAND
                12% FLY ASH
              8% PCM-400 RESIN
                 3.24% BPO
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY          11760
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)           4.56
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    REQUIRES FORMULATION
*
    MANUFACTURER: ROHM & HAAS    INDEPENDENCE MALL WEST
PHILADELPHIA PA 19105
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:    HMWM (METHACRYLATE)-1100      DATE OF LAST TEST: 4 /84
                 FORMULA
               44% PEA GRAVEL
                44% PCC SAND
                12% FLY ASH
                  8% RESIN
                  2% CONAP
                   2% CHP

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  5585
      24-HOURS:  6755
      28-DAYS:   6625

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    2155
          COMPRESSIVE DRY            6265
          COMPRESSIVE WET
          BOND TO DRY PCC
          BOND TO SSD PCC            520
          ABRASION LOSS (GRAMS)      7
               E (X10 6)             1.71
          SPECIFIC GRAVITY;          2.28
          UNIT WEIGHT (#/CF)         142.5
          ABSORPTION (%):            .6
    COMMENTS:    REQUIRES FORMULATION

   MANUFACTURER: ROHM & HAAS CO.    INDEPENDENCE MALL WEST
PHILADELPHIA PA 19105
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:            HORN 240              DATE OF LAST TEST: 9 /83
               FORMULA
              21.30% LIQUID
              78.70% POWDER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   540
        3-HOURS:  1590
       24-HOURS:  3850
       28-DAYS:   9405

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    545
           COMPRESSIVE DRY            4935
           COMPRESSIVE WET            4365
           BOND TO DRY PCC            495
           BOND TO SSD PCC            175
           ABRASION LOSS (GRAMS)      19
                E (X10 6)             4.07
           SPECIFIC GRAVITY;          2.40
           UNIT WEIGHT (#/CF)        149.8
           ABSORPTION (%):            3.3
     COMMENTS:    *
*
    MANUFACTURER: A.C. HORN INC.   1717 PATERSON PLANE RD.   NORTH BREGEN N.J.   07
LOCAL DISTRICT: A.C. HORN--L.A. MICHELLE 213-269-1846
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:            IC-201              DATE OF LAST TEST: 4 /85
                FORMULA
                90.6% IC-201
                 9.4% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   2340
        3-HOURS:  5725
       24-HOURS:  9850
       28-DAYS:   11750

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  730
           COMPRESSIVE DRY          6235
           COMPRESSIVE WET          5435
           BOND TO DRY PCC          490
           BOND TO SSD PCC          385
           ABRASION LOSS (GRAMS)    24
                E (X10 6)           5.25
           SPECIFIC GRAVITY;        2.30
           UNIT WEIGHT (#/CF)      143.1
           ABSORPTION (%):          1.0
     COMMENTS:    HIGH ALUMINA CEMENT BASED
STEEL FIBERS INCORPORATED
    MANUFACTURER: DRY MIX PRODUCTS CO.  P.O. BOX 730  ROSEVILLE CA  95661
916-783-8168
```

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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:          KRYPTON FSM              DATE OF LAST TEST: 5 /83
              FORMULA
            3.87% PART A=LIQUID
            96.13% PART B AGGREGATE
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:       50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  6900
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    3415
           COMPRESSIVE DRY            7365
           COMPRESSIVE WET
           BOND TO DRY PCC            800
           BOND TO SSD PCC            430
           ABRASION LOSS (GRAMS)
                E (X10 6)             1.41
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%);
     COMMENTS:    BLUE GREY COLOR
*
    MANUFACTURER: KRYPTON INDUSTRIES  MARINA DEL REY  CA 90291
213-827-8906
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:            LF-39                DATE OF LAST TEST: 12/82
                FORMULA
                92.0% LF-39
                 8.0% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  5725
       28-DAYS:   9715

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  560
           COMPRESSIVE DRY          4095
           COMPRESSIVE WET
           BOND TO DRY PCC          95
           BOND TO SSD PCC          475
           ABRASION LOSS (GRAMS)    21
                E (X10 6)           1.2
           SPECIFIC GRAVITY;        2.26
           UNIT WEIGHT (#/CF)       141
           ABSORPTION (%):          3.05
     COMMENTS:
*
    MANUFACTURER: MASTER BUILDERS  HAYWARD CA
415-786-3118
```

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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:       MARK 163 FLEXOGRID        DATE OF LAST TEST: 4 /85
                 FORMULA
                  9% PART A
                 4.03% PART B
            86.97% MONTEREY 16X30 SAND
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2265
           COMPRESSIVE DRY            5530
           COMPRESSIVE WET
           BOND TO DRY PCC            1200
           BOND TO SSD PCC            350
           ABRASION LOSS (GRAMS)      7
                E (X10 6)             .4
           SPECIFIC GRAVITY;          1.96
           UNIT WEIGHT (#/CF)       122.4
           ABSORPTION (%):            0.9
     COMMENTS:    *
*
    MANUFACTURER: POLY CARB    33095 BAINBRIDGE ROAD
SOLON OHIO 44139      216-248-1223
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          M P CONCRETE          DATE OF LAST TEST: 5 /84
              FORMULA
              80.1% POWDER
              19.9% LIQUID
                   *
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:      60

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   1150
       3-HOURS:  1445
      24-HOURS:  3965
      28-DAYS:   8500

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE
          COMPRESSIVE DRY
          COMPRESSIVE WET
          BOND TO DRY PCC
          BOND TO SSD PCC
          ABRASION LOSS (GRAMS)
               E (X10 6)
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: CONCRETE PRODUCTS INC   P.O. BOX 1011   WOODLAND CA 95695
916-666-3633
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```
          ****************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ****************************************
TRADE NAME:        NECO CRETE 360          DATE OF LAST TEST: 5 /85
                FORMULA
               19.71% LIQUID
              80.29% AGGREGATE
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   540
        3-HOURS:  2635
       24-HOURS:  4880
       28-DAYS:   7875

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)    29
                E (X10 6)
           SPECIFIC GRAVITY:
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
   MANUFACTURER: NECO INDUSTRIAL PLASTICS    4525 SAUNDERS ROAD
HOUSTON TEXAS 77093     713-692-5971
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          NFS BINDER          DATE OF LAST TEST: 9 /82
              FORMULA
             27% NFS BINDER
             37.9% PCC SAND
               8.0% WATER
                  *
                  *
                  *

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  135
      24-HOURS:  8970
      28-DAYS:   13860

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    75
          COMPRESSIVE DRY            6885
          COMPRESSIVE WET
          BOND TO DRY PCC
          BOND TO SSD PCC
          ABRASION LOSS (GRAMS)
               E (X10 6)             4.62
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: DRY MIX PRODUCTS   ROSEVILLE CA
916-783-8168
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          PATCH COTE            DATE OF LAST TEST: 8 /82
               FORMULA
              10.69% LIQUID
              89.31% POWDER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  2680
       24-HOURS:  2940
       28-DAYS:   5820

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    330
           COMPRESSIVE DRY            2665
           COMPRESSIVE WET
           BOND TO DRY PCC            10
           BOND TO SSD PCC            245
           ABRASION LOSS (GRAMS)      21
                E (X10 6)             .93
           SPECIFIC GRAVITY;          2.03
           UNIT WEIGHT (#/CF)         126.7
           ABSORPTION (%):            10.16
     COMMENTS:    *
*
    MANUFACTURER: STONE COTE INC.    15257 SOUTH KEELER   OLATHE KANSAS 66061
913-782-7849
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        PERCOL URETHANE          DATE OF LAST TEST: 3 /85
              FORMULA
          44%       PEA GRAVEL
           44%       PCC SAND
              12% FLY ASH
           5% RESIN PERCOL A
           5% RESIN PERCOL B
                  .*

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
      1-HOUR:   2105
      3-HOURS:  2550
     24-HOURS:  2620
     28-DAYS:

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                  1665
          COMPRESSIVE DRY          4440
          COMPRESSIVE WET
          BOND TO DRY PCC          1240
          BOND TO SSD PCC          515
          ABRASION LOSS (GRAMS)
               E (X10 6)           3
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:
  PRES FORMULATION
   MANUFACTURER: ARNCO     5141 FIRESTONE PLACE     SOUTH GATE CA 90280
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        POLY AD CONCRETE          DATE OF LAST TEST: 12/84
                 FORMULA
             36.14% PEA GRAVEL
            36.14% T.P. PCC SAND
            18.23% TYPE III CEMENT
               1.8% POLY AD A
               .39% POLY AD B
            .07% MELMENT + 7.23% WATER

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  1995
       28-DAYS:   8150

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)     18
                E (X10 6)            3.83
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:     *
*
    MANUFACTURER: REVOLAN INC     P.O. BOX 18922     SAN JOSE CA 95158
408-288-8658
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:     C-609 POLYESTER RESIN        DATE OF LAST TEST: 5 /83
                FORMULA
              66.67% PCC SAND
             33.33% PEA GRAVEL
                 13% RESIN
                  1% MEKP
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  3000
      24-HOURS:  9110
      28-DAYS:   11070

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    2100
          COMPRESSIVE DRY            7790
          COMPRESSIVE WET
          BOND TO DRY PCC            770
          BOND TO SSD PCC            300
          ABRASION LOSS (GRAMS)      3
               E (X10 6)             2.57
          SPECIFIC GRAVITY;          2.21
          UNIT WEIGHT (#/CF)         137.9
          ABSORPTION (%):            .5
    COMMENTS:    REQUIRES FORMULATION

   MANUFACTURER: CHAGRIN VALLEY INDUSTRIES    147 BELL ST
                 CHAGRIN FALLS   OHIO 44022
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          POLYTEX 950            DATE OF LAST TEST: 1 /83
                FORMULA
               44% AGG. SAND
               44% PEA GRAVEL
                12% FLY ASH
              8.4% POLYTEX 950
              1% DMA + 1% CHP
                   1% CON

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   12200
        3-HOURS:
       24-HOURS:  14750
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2660
           COMPRESSIVE DRY            13065
           COMPRESSIVE WET
           BOND TO DRY PCC            825
           BOND TO SSD PCC            290
           ABRASION LOSS (GRAMS)      6
                E (X10 6)             4.88
           SPECIFIC GRAVITY;          1.98
           UNIT WEIGHT (#/CF)         123.8
           ABSORPTION (%):            7
     COMMENTS:    *
*
    MANUFACTURER: CELANESE CORPORATION     LOS ANGELES CA
213-266-4435
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:            POR-ROK                DATE OF LAST TEST: 5 /84
                FORMULA
               84.23% POR-ROK
                15.77% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
       1-HOUR:    3925
        3-HOURS:  3750
       24-HOURS:  4050
       28-DAYS:   7175

           24 HOUR TESTS  (PSI)
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           NUMBER OF CU.FT.:
           ABSORPTION:
     COMMENTS:    *
*
    MANUFACTURER: LEHN & FINK INDUSTRIAL PRODUCTS   DIVISION OF STERLING DRUGS INC
225 SUMMIT AVE   MONTVALE N.J. 07645    201-391-3500
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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:        PRECO PIKE PATCH          DATE OF LAST TEST: 11/84
                 FORMULA
             88.45% PIKE PATCH
                 11.55% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   3670
       3-HOURS:  4405
      24-HOURS:  5350
      28-DAYS:   8180

      24 HOUR TESTS (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY:
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
    COMMENTS:    *
*
    MANUFACTURER: PRECO   55 SKYLINE DR.    PLAINVIEW NEW YORK 11803
800-645-3954          212-445-7775(NEW YORK)
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:      QUICKCRETE CEMENT          DATE OF LAST TEST: 11/84
                 FORMULA
            84.22%QUICK-SET CEMENT
                15.78% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      50

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   90
       3-HOURS:  120
      24-HOURS:  3640
      28-DAYS:   7485

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    350
          COMPRESSIVE DRY            2530
          COMPRESSIVE WET
          BOND TO DRY PCC            275
          BOND TO SSD PCC            320
          ABRASION LOSS (GRAMS)      23
               E (X10 6)             4.12
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: QUICKCRETE COMPANIES   1790 CENTURY CIRCLE
   E. ATLANTA GA 30345       404-634-9100
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:      QUICK CRETE GROUT          DATE OF LAST TEST: 11/84
               FORMULA
           85.72%NON-SHRINK GROUT
               14.28% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  4525
       28-DAYS:   10200

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                  415
          COMPRESSIVE DRY          3245
          COMPRESSIVE WET
          BOND TO DRY PCC          110
          BOND TO SSD PCC          335
          ABRASION LOSS (GRAMS)    18
               E (X10 6)           2.89
          SPECIFIC GRAVITY;        2.24
          UNIT WEIGHT (#/CF)      140.4
          ABSORPTION (%):          3.1
     COMMENTS:    *
*
    MANUFACTURER: QUICKCRETE COMPANIES    1790 CENTURY CIRCLE
N.E. ATLANTA GA 30345     404-634-9100
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:    QUICKCRETE ROAD REPAIR      DATE OF LAST TEST: 11/84
                FORMULA
             88.01% ROAD REPAIR
              11.99% WATER
                   *
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   1780
        3-HOURS:  2490
       24-HOURS:  4655
       28-DAYS:   8115

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    615
           COMPRESSIVE DRY            3705
           COMPRESSIVE WET
           BOND TO DRY PCC            455
           BOND TO SSD PCC            460
           ABRASION LOSS (GRAMS)      25
                E (X10 6)             2.97
           SPECIFIC GRAVITY;          2.00
           UNIT WEIGHT (#/CF)        124.7
           ABSORPTION (%):            5.2
     COMMENTS:    *

    MANUFACTURER: QUICKCRETE COMPANIES    1790 CENTURY CIRCLE
    E. ATLANTA GA 30345     404-634-9100
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          QUICK-SET              DATE OF LAST TEST: 11/80
               FORMULA
              80% QUICK SET
                20% WATER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   1245
        3-HOURS:  1305
       24-HOURS:  2440
       28-DAYS:   5225

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  275
           COMPRESSIVE DRY          1685
           COMPRESSIVE WET
           BOND TO DRY PCC          20
           BOND TO SSD PCC          190
           ABRASION LOSS (GRAMS)    25
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT ($/CF)
           ABSORPTION (%):
     COMMENTS:
*
    MANUFACTURER: DRY MIX PRODUCTS   ROSEVILLE CA
916-783-8168
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        RAPID SET CEMENT          DATE OF LAST TEST: 2 /84
                FORMULA
            35.42% PEA GRAVEL
               35.42% SAND
            19.06% VHE CEMENT
               10.10% WATER
                    *
                    *

COMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   2500
       3-HOURS:  3130
      24-HOURS:  4675
      28-DAYS:   7040

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                  545
          COMPRESSIVE DRY          4045
          COMPRESSIVE WET          3535
          BOND TO DRY PCC          240
          BOND TO SSD PCC          295
          ABRASION LOSS (GRAMS)    23
               E (X10 6)           4.27
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: CHEM TECH SERVICES  SHERMAN OAKS CA
213-904-6111
```

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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME: RAPID SET CONCRETE MIX 3/8"    DATE OF LAST TEST: 4 /84
                FORMULA
              90.9% RAPID SET
                 9.1% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   2382
        3-HOURS:  3130
       24-HOURS:  4145
       28-DAYS:   6250

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:     *
*
    MANUFACTURER: RAPID SET PRODUCTS CO.   VAN NUYS CA 91411
*
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:      RAPID SET MORTAR MIX        DATE OF LAST TEST: 4 /84
                 FORMULA
              85.22% MORTAR MIX
                 14.78% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   500
       3-HOURS:  1005
      24-HOURS:
      28-DAYS:   1925

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE
          COMPRESSIVE DRY
          COMPRESSIVE WET
          BOND TO DRY PCC
          BOND TO SSD PCC
          ABRASION LOSS (GRAMS)
               E (X10 6)
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: RAPID SET PRODUCTS INC.    VAN NUYS CA 91411
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:    REVOPLATE RS-101 FLEX        DATE OF LAST TEST: 5 /85
                FORMULA
               44% PEA GRAVEL
                44% PCC SAND
                12% FLY ASH
                 8% 101FLEX
              2% NEODECONOATE
                   2% CHP

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  7250
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2035
           COMPRESSIVE DRY            10635
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)      8
                E (X10 6)             1.9
           SPECIFIC GRAVITY;          2.33
           UNIT WEIGHT (#/CF)         145.3
           ABSORPTION (%):            .1
     COMMENTS:    *
*
    MANUFACTURER: REVOLAN INC.   P.O. BOX 18922   SAN JOSE CA 95158
408-288-8658
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        REVOPLATE RS-200          DATE OF LAST TEST: 5 /85
                 FORMULA
               44% PEA GRAVEL
                44% PCC SAND
                12% FLY ASH
               8% RESIN RS-200
              3% NEO DECONOATE
                   2% CHP

RECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  8400
      24-HOURS:  12055
      28-DAYS:   13025

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                  2190
          COMPRESSIVE DRY          12185
          COMPRESSIVE WET          11620
          BOND TO DRY PCC          955
          BOND TO SSD PCC          650
          ABRASION LOSS (GRAMS)    6
               E (X10 6)           2.34
          SPECIFIC GRAVITY;        2.34
          UNIT WEIGHT (#/CF)       146.1
          ABSORPTION (%):          .1
    COMMENTS:    *

   MANUFACTURER: REVOLAN INC.     P.O. BOX 18922    SAN JOSE CA 95158
408 288-8658
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          REVSEAL 100            DATE OF LAST TEST: 3 /84
                FORMULA
            45%       PEA GRAVEL
             45%       PCC SAND
                10% FLY ASH
                  8% RESIN
                   2% CHP
                 2% CO NAP

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  9755
       24-HOURS:  11990
       28-DAYS:   15165

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2275
           COMPRESSIVE DRY            13120
           COMPRESSIVE WET            9905
           BOND TO DRY PCC            840
           BOND TO SSD PCC            1065
           ABRASION LOSS (GRAMS)      8
                E (X10 6)             3.89
           SPECIFIC GRAVITY;          2.29
           UNIT WEIGHT (#/CF)        142.6
           ABSORPTION (%):            1.2
     COMMENTS:     *
*
    MANUFACTURER: REVOLAN INC.    P.O.BOX 18922    SAN JOSE CA 95158
408-238-8658
```

```
*****************************************
*   S U M M A R Y   O F   R E S-U L T S   *
*****************************************
TRADE NAME:        SET 45 CUCAMONGA          DATE OF LAST TEST: 1 /85
                 FORMULA
                 92.3% SET 45
                  7.7% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:      60

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:
       3-HOURS:  3030
      24-HOURS:  6150
      28-DAYS:

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    385
          COMPRESSIVE DRY            3970
          COMPRESSIVE WET            3245
          BOND TO DRY PCC            490
          BOND TO SSD PCC            305
          ABRASION LOSS (GRAMS)      30
               E (X10 6)             3.47
          SPECIFIC GRAVITY;          2.15
          UNIT WEIGHT (#/CF)        134.3
          ABSORPTION (%):            6.6
    COMMENTS:    *

   MANUFACTURER: MASTER BUILDERS     26203 PRODUCTION AVE     HAYWARD CA 94545
415-786-3114
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          SET 45 COLD            DATE OF LAST TEST: 8 /83
                FORMULA
               91.65% SET 45
                8.35% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   7900
        3-HOURS:  8665
       24-HOURS:  10225
       28-DAYS:   12405

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    830
           COMPRESSIVE DRY            7830
           COMPRESSIVE WET            7580
           BOND TO DRY PCC            865
           BOND TO SSD PCC            540
           ABRASION LOSS (GRAMS)      30
                E (X10 6)             4.2
           SPECIFIC GRAVITY;          2.17
           UNIT WEIGHT (#/CF)         135.6
           ABSORPTION (%):            5.5
     COMMENTS:    *
*
    MANUFACTURER: MACEDONIA  OHIO MFG----MASTER BUILDERS   26203 PRODUCTION AVE
HAYWARD CA 94545      415-786-3114
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          SET 45 HOT            DATE OF LAST TEST: 11/82
              FORMULA
           91.65% SET 45 HOT
              8.35% WATER
                   *
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  2040
       24-HOURS:  5315
       28-DAYS:   8490

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    545
           COMPRESSIVE DRY            5335
           COMPRESSIVE WET            4315
           BOND TO DRY PCC            565
           BOND TO SSD PCC            300
           ABRASION LOSS (GRAMS)      26
                E (X10 6)             3.21
           SPECIFIC GRAVITY;          2.14
           UNIT WEIGHT (#/CF)        133.4
           ABSORPTION (%):            5.3
     COMMENTS:    *
*
    MANUFACTURER: MACEDONIA  OHIO MFG----MASTER BUILDERS    26203 PRODUCTION AVE
HAYWARD CA 94545        415-786-3114
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:      SET INSTANT CONCRETE        DATE OF LAST TEST: 12/84
                 FORMULA
              88.80% INSTANT SET
                 11.20% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   440
        3-HOURS:  415
       24-HOURS:  3840
       28-DAYS:   7885

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:
*
    MANUFACTURER: SET PRODUCTS---MASTER BUILDERS   26203 PRODUCTION AVE
HAYWARD CA 94545     415-786-3114
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        SET VERTIPATCH          DATE OF LAST TEST: 8 /83
              FORMULA
            84.22% VERTIPATCH
             5.26% ACRYL SET
              10.52% WATER
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  1365
       28-DAYS:   2230

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *

    MANUFACTURER: MASTER BUILDERS  26203 PRODUCTION AVE     HAYWARD CA
:15-786-3114
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        SIKA PRONTO II          DATE OF LAST TEST: 3 /85
              FORMULA
          7.39% PRONTO LIQUID
          63.64% PRONTO AGGREGATE
           28.97% PEA GRAVEL
                  *
                  *
                  *

RECOMMENDED MAXIMUM EXTENSION:      50

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  11485
       24-HOURS:  11365
       28-DAYS:   12140

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  2025
           COMPRESSIVE DRY          8445
           COMPRESSIVE WET
           BOND TO DRY PCC          1120
           BOND TO SSD PCC          1000
           ABRASION LOSS (GRAMS)    8
                E (X10 6)           2.32
           SPECIFIC GRAVITY;        2.17
           UNIT WEIGHT (#/CF)      135.8
           ABSORPTION (%):          0.5
     COMMENTS:    *
*
    MANUFACTURER: SIKA CORP.       SAN FRANCISCO CA
415-775-1551
```

```
          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:          SIKATOP III              DATE OF LAST TEST: 5 /83
                FORMULA
              7.59% "A" LIQUID
             54.91% "B" POWDER
             37.50% PEA GRAVEL
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:       60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   325
        3-HOURS:  430
       24-HOURS:  4415
       28-DAYS:   8565

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    480
           COMPRESSIVE DRY            3690
           COMPRESSIVE WET            3180
           BOND TO DRY PCC            300
           BOND TO SSD PCC            160
           ABRASION LOSS (GRAMS)      14
                E (X10 6)             3.46
           SPECIFIC GRAVITY;          2.33
           UNIT WEIGHT (#/CF)         145
           ABSORPTION (%):            1.75
     COMMENTS:
*
    MANUFACTURER: SIKA CORP.     SAN FRANCISCO CA     415-775-1551
*
```

```
*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          SILIKAL                DATE OF LAST TEST: 8 /82
               FORMULA
               8.1% LIQUID
               91.9% POWDER
                    *
                    *
                    *
                    *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  6680
       24-HOURS:  8225
       28-DAYS:   9995

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2390
           COMPRESSIVE DRY            5390
           COMPRESSIVE WET
           BOND TO DRY PCC            795
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)      5
                E (X10 6)
           SPECIFIC GRAVITY;          2.26
           UNIT WEIGHT (#/CF)         141.1
           ABSORPTION (%):            .01
     COMMENTS:    *
*
    MANUFACTURER: TRANSPO INDUSTRIES INC.     111 CEDAR STREET     NEW ROCHELLE NY
914-636-1000
```

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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:          SILIKAL T7            DATE OF LAST TEST: 2 /81
               FORMULA
            58%SILIKAL POWDER T7
              35%  PEA GRAVEL
             7% CONCRESIVE 2010
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:      60

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                  1415
           COMPRESSIVE DRY          6855
           COMPRESSIVE WET
           BOND TO DRY PCC          20
           BOND TO SSD PCC          175
           ABRASION LOSS (GRAMS)    3
                E (X10 6)
           SPECIFIC GRAVITY;        2.42
           UNIT WEIGHT (#/CF)       150.1
           ABSORPTION (%):          .1
     COMMENTS:

    MANUFACTURER: TRANSPO MATERIALS INC.     NEW ROCHELLE NY
914-636-1000
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S  *
*****************************************
TRADE NAME:          STEEL GRIP            DATE OF LAST TEST: 9 /83
              FORMULA
          21.67% PORTLAND CEMENT
            64.99% PCC SAND
              9.52% WATER
              3.82% M-1000
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   280
       3-HOURS:  650
      24-HOURS:  1060
      28-DAYS:   2100

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    355
          COMPRESSIVE DRY            1590
          COMPRESSIVE WET
          BOND TO DRY PCC            175
          BOND TO SSD PCC            210
          ABRASION LOSS (GRAMS)      17
               E (X10 6)             1.16
          SPECIFIC GRAVITY;          1.94
          UNIT WEIGHT (#/CF)        121.1
          ABSORPTION (%):            7.5
    COMMENTS:    *
*
   MANUFACTURER: ASTRO-STEEL GRIP INTERNATIONAL INC.     342 HARBOR WAY
SO. SAN FRANCISCO CA 94080      415-873-0192
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:          THERMALCRETE          DATE OF LAST TEST: 9 /81
                FORMULA
                19.9% LIQUID
                80.1% POWDER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:       100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   2690
       3-HOURS:  4515
      24-HOURS:  7060
      28-DAYS:

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE                    555
          COMPRESSIVE DRY            5285
          COMPRESSIVE WET
          BOND TO DRY PCC            515
          BOND TO SSD PCC            175
          ABRASION LOSS (GRAMS)
               E (X10 6)
          SPECIFIC GRAVITY:          2.24
          UNIT WEIGHT (#/CF)        139.9
          ABSORPTION (%):            4.7
    COMMENTS:

   MANUFACTURER: THERMALCRETE SYSTEMS INC.    5603 ARROW HWY.
 [illegible]LAIR CA 91763      714-946-5745
```

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          ******************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ******************************************
TRADE NAME:            THORITE                DATE OF LAST TEST: 5 /84
                 FORMULA
                86.95% THORITE
                 13.05% WATER
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   785
        3-HOURS:  1270
       24-HOURS:  1900
       28-DAYS:   3930

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:     *
*
    MANUFACTURER: STANDARD DRY WALL PRODUCT
NEWARK CA 94560
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
RADE NAME:     THORO MANHOLE LEVELER        DATE OF LAST TEST: 5 /83
                FORMULA
            87.3% MANHOLE LEVELER
                12.7% WATER
                     *
                     *
                     *
                     *

ECOMMENDED MAXIMUM EXTENSION:

C A L I F O R N I A   T E N T A T I V E   T E S T S
     COMPRESSIVE STRENGTH (PSI)
       1-HOUR:   545
       3-HOURS:  745
      24-HOURS:  1415
      28-DAYS:   4055

     24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
          FLEXURE
          COMPRESSIVE DRY
          COMPRESSIVE WET
          BOND TO DRY PCC
          BOND TO SSD PCC
          ABRASION LOSS (GRAMS)
               E (X10 6)
          SPECIFIC GRAVITY;
          UNIT WEIGHT (#/CF)
          ABSORPTION (%):
    COMMENTS:    *

   MANUFACTURER: - THORO SYTEMS PRODUCTS INC.  7800 N.W. 38th STREET
   MIAMI, FLA, 33166
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        ******************************************
        *   S U M M A R Y   O F   R E S U L T S   *
        ******************************************
TRADE NAME:     THORO POLYMER CONCRETE      DATE OF LAST TEST: 5 /84
                 FORMULA
               85.66% PART "A"
               14.34% PART "B"
                      *
                      *
                      *
                      *

RECOMMENDED MAXIMUM EXTENSION:      90

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  8475
       24-HOURS:  8735
       28-DAYS:

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    2125
           COMPRESSIVE DRY            9080
           COMPRESSIVE WET
           BOND TO DRY PCC            1075
           BOND TO SSD PCC            895
           ABRASION LOSS (GRAMS)      11
                E (X10 6)             4.6
           SPECIFIC GRAVITY;          2.19
           UNIT WEIGHT (#/CF)        136.9
           ABSORPTION (%):            0.5
     COMMENTS:    PART "A": SELECTED SILICA AGGREGATE MIX
PART "B": REACTIVE ACRYLIC DILUENT
    MANUFACTURER: THORO SYSTEMS PRODUCTS INC.    7800 N.W. 38TH STREET
MIAMI FLA 33166
```

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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:     THORO ROAD PATCH II        DATE OF LAST TEST: 5 /85
                FORMULA
          89.14% ROAD PATCH II
             3.63% ACRYL 60
              7.23% WATER
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:   505
        3-HOURS:  765
       24-HOURS:  1660
       28-DAYS:   3400

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)    25
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *

    MANUFACTURER: THORO SYSTEMS PRODUCTS INC.    7800 N.W. 38TH STREET
MIAMI FLA 33166
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*****************************************
*   S U M M A R Y   O F   R E S U L T S   *
*****************************************
TRADE NAME:        THOR VINYL PATCH          DATE OF LAST TEST: 10/80
              FORMULA
          84.9% THOR VINYL PATCH
              15.1% WATER
                   *
                   *
                   *
                   *

RECOMMENDED MAXIMUM EXTENSION:       100

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:
       24-HOURS:  1575
       28-DAYS:   4145

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE                    320
           COMPRESSIVE DRY            1830
           COMPRESSIVE WET
           BOND TO DRY PCC            430
           BOND TO SSD PCC            505
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:     *
*
    MANUFACTURER: DRY MIX PRODUCTS    ROSEVILLE CA
916-783-8168
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          ****************************************
          *   S U M M A R Y   O F   R E S U L T S   *
          ****************************************
TRADE NAME:          VANDEX MORTAR            DATE OF LAST TEST: 10/84
                FORMULA
            85.14% VANDEX MORTAR
                14.86% WATER
                     *
                     *
                     *
                     *

RECOMMENDED MAXIMUM EXTENSION:

 C A L I F O R N I A   T E N T A T I V E   T E S T S
      COMPRESSIVE STRENGTH (PSI)
        1-HOUR:
        3-HOURS:  170
       24-HOURS:  375
       28-DAYS:   5050

      24 HOUR TESTS  (PSI)-MAXIMUM AGGREGATE EXTENSION
           FLEXURE
           COMPRESSIVE DRY
           COMPRESSIVE WET
           BOND TO DRY PCC
           BOND TO SSD PCC
           ABRASION LOSS (GRAMS)
                E (X10 6)
           SPECIFIC GRAVITY;
           UNIT WEIGHT (#/CF)
           ABSORPTION (%):
     COMMENTS:    *
*
    MANUFACTURER: VANDEX INC.    300 BROAD STREET   STAMFORD CT 06901
203-322-7020
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APPENDIX II

SPECIFICATIONS

Specification for Packaged Materials to be Used for Rapid Set Repairs of Portland Cement Concrete Pavement and Structures

SCOPE - This specification covers packaged, single or multiple component mortar and concrete repair materials for rapid repairs to portland cement concrete pavements and structures. This specification also covers organic based patching materials such as epoxies, methacrylates, polyesters, urethanes, and various latex and emulsion combinations.

DESCRIPTION - The material shall be similar in color to portland cement concrete and shall have the capability of being mixed and placed in a similar manner. Maximum aggregate gradation shall be 3/8 inch unless otherwise specified. The patching material must yield a permanent patch that can be subjected to traffic within three hours. The patching material shall be Type _____ and Class(es) _____. The following types and uses shall generally be as shown below:

Type GP: Type GP patching materials are for patching prestressed, reinforced or nonreinforced portland cement concrete and shall not contain more than .05% soluble chlorides per Calif. Test 415 or .25% water soluble sulfates as SO_4 per Calif. Test 417 by weight.

Type SP: Type SP patching materials are for patching nonreinforced portland cement concrete only.

Type GP and Type SP patching materials shall specifically be classed in the following manner:

Class W: Premixed Water-Activated: These materials shall be water-activated to be used complete as received by adding water only. An aggregate extension may be permitted as recommended by the manufacturer.

Class L: Premixed, Liquid Activator: These materials contain selected aggregates and a nonwater activator formulated for use, complete, as received. An aggregate extension may be permitted in conformance to the manufacturer's instructions.

Class P: Premixed, Liquid Binder: These materials contain selected aggregates and binder liquid with either separate or incorporated activators formulated for use, complete as received. Aggregate extension may be permitted in conformance to the manufacturer's instructions.

Class B: Binder Only: These materials contain no aggregate. The aggregate must be added by the user in conformance to the manufacturer's instructions.

Packaging and Storage: This material shall be packaged in strong, moisture proof bags or other suitable containers capable of withstanding shipping, normal handling, and storage without breakage or loss. Under storage conditions of 40°F to 90°F with a maximum relative humidity of 90%, the material must have a minimum storage life of one year.

Each container of the patching system components shall be clearly and durably labeled and marked in accordance to ASTM C-928, Section 10 and the following information shown:

1. Component designation, if two or more components.
2. Manufacturer's lot number.
3. Mixing ration and directions.
4. Potential hazards and precautions shall be displayed in accordance with the Federal Hazardous Products Labeling Act.
5. Recommended clean-up solvents and disposal methods.

PHYSICAL REQUIREMENTS AND TEST METHODS - Rapid Setting Patching Materials shall conform to the following physical requirements when tested in accordance with California Test 551. Copies of California tentative test methods are available from the Transportation Laboratory, 5900 Folsom Blvd., Sacramento, CA 95819, (916)739-2324.

The following tests shall be conducted on the "neat" or "as received" material, or with formulated aggregates as recommended by the manufacturer in the case of "Binder Only."

Physical Requirements

1. Setting Time

a.	Initial Set, minutes	15 Minimum
b.	Final Set, minutes	25 Minimum

2. Minimum Compressive Strengths

a.	3 hours, psi	3000 Minimum
b.	24 hours, psi	5000 Minimum

3. Abrasion Resistance

24 hours, grams loss	25 Maximum

4. Shrinkage, % (ASTM C596)

4 days	0.13 Maximum

The following 24-hour tests shall be conducted on the packaged material, extended with 3/8" pea gravel to the maximum rate recommended by the manufacturer.

5.	Flexural Strength, psi	500 Minimum
6.	Bonding Strength to dry PCC, psi	400 Minimum
7.	Bonding Strength to SSD PCC, psi	300 Minimum
8.	Absorption, %	10 Maximum
9.	Freeze/Thaw Resistance, Cycles	150 Minimum

Mix water shall conform to Section 90-2.03, "Water" of the Standard Specifications.

Test Methods: Mixing instructions of the manufacturer will be followed. If a specific bonding agent or cure is required, submit necessary sample and instructions for use.

Acceptance: Samples of materials to be used without prior approval by Caltrans shall be submitted to Transportation Laboratory a minimum of 45 days before intended use. Untested rapid setting materials to be used in freezing and thawing areas, shall be submitted at least 90 days before intended use for testing. Control samples of previously released materials shall be submitted for testing at least 10 working days before intended use. Sample size to be submitted shall be a minimum of 45 lbs and be submitted in unopened units.

No material shall be incorporated in the work prior to approval by the Transportation Laboratory unless accompanied by Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance" of the Standard Specifications.

Specification to Remove Concrete Deck Surfaces

This work shall consist of removing portions of the portland cement concrete deck surface to a depth of 1/8 inch, abrasive blasting and blowing clean the deck surface as shown on the plans and as described in these special provisions.

The method of concrete removal shall be selected by the contractor except that scarifiers, coldplaners, scabblers, and similar types of equipment or procedures that leave fractured aggregate or otherwise damage the concrete surface to remain shall not be used.

High pressure water jet equipment shall have rotating jets and be rated at no less than 35,000 psi. Adequate means shall be used to prevent water from the jetting operation from flowing across traffic lanes, or flowing into gutters or waterways.

Equipment shall be fitted with suitable traps, filters, drip pans or other devices, as necessary, to prevent oil or other deleterious material from being deposited on the deck.

After the deck has been blown clean, unsound concrete shall be removed, as specified under "Remove Unsound Concrete" of these special provisions. When the removal of unsound concrete has been completed, the entire surface shall be abrasive blast cleaned of all surface contaminants. If the surface becomes contaminated at any time prior to placing the overlay, the surface shall be recleaned.

Immediately prior to placement of the bond coat, the entire deck area shall be cleaned by compressed air blasting. If the surface becomes contaminated at any time prior to placing the overlay, the surface shall be recleaned and the bond coat shall be reapplied to the affected areas.

All removed materials shall become the property of the contractor and shall be disposed of in accordance with Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Remove concrete deck surface will be measured by the square foot of concrete deck surface to be removed based on dimensions shown on the plans.

The contract price paid per square foot for remove concrete deck surface shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in removing concrete deck surface, except remove unsound concrete, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the engineer.

Specification for Polyester Styrene Concrete Overlay

This work shall consist of constructing a polyester concrete overlay, applying prime coat and preparing surface in accordance with the details shown on the plans and these special provisions.

MATERIALS - Prior to constructing the polyester styrene concrete overlay and applying the prime coat on the bridge deck, the contractor shall arrange to have the material supplier furnish (1) technical service relating to application of material and (2) health and safety training for personnel who are to handle the polyester styrene concrete and the prime coat.

Cleaning and flushing of equipment, tools, etc., shall be done with an appropriate solvent, as approved by the engineer, in such a manner to minimize personal and environmental hazards. A soap and water wash station shall be provided for the workers at the job site.

POLYESTER CONCRETE - shall consist of polyester resin binder and aggregate. The resin shall be an unsaturated isophthalic polyester-styrene copolymer, wax-free, and shall conform to the following requirements:

Polyester Styrene Resin Binder

Viscosity	75 to 200 cp	ASTM D-2393
Specific Gravity	1.05 to 1.10 at 77°F	ASTM D-2849
Elongation	35% minimum	ASTM D-638
Tensile Strength	2,500 psi minimum	ASTM D-638
Conditioning	18h/25°C/50% + 5h/70°C	ASTM D-618
Styrene Content	40% to 50% by weight as volatiles	ASTM D-2369
Silane Coupler	1.0% (by weight of polyester-styrene resin)	
PCC Saturated Surface Dry Bond Strength	500 psi min. @ 24 hours	Calif. Test 551

The silane coupler shall be an organosilane ester, gammamethacryloxypropyltrimethoxysilane.

PRIME COAT - The prepared surface shall receive a high molecular weight methacrylate prime coat conforming to the following:

High Molecular Weight Methacrylate Resin

Viscosity:	<25 cp (Brookfield RVT w/UL adaptor, 50 RPM @ 77°F)	ASTM D-2393
Specific Gravity:	1.01 to 1.10 at 77°F	ASTM D-2849
Flash Point:	>180°F	ASTM D-3278
Vapor Pressure:	<1.0 mm Hg at 77°F	ASTM D-323
PCC Saturated Surface Dry Bond Strength	>500 psi in 24 hrs at 77°F	Calif. Test 551

The promoter/initiator system for the methacrylate resin shall consist of a metal dryer and peroxide. The promoter and initiator, if supplied separate from the resin, shall not contact each other directly. The containers of promoters and initiators shall not be stored in a manner that will allow leakage or spillage from one material to contact the containers or material of the other.

Aggregate for polyester concrete shall conform to the requirements of Section 90-2.02, "Aggregates," of the Standard Specifications and either of the following combined aggregate gradings:

Combined Aggregate Grading

Sieve size	1/2" Max. % Passing	3/8" Max. % Passing
1/2"	100	100
3/8"	83-100	100
No. 4	65-82	62-85
No. 8	45-64	45-67
No. 16	27-48	29-50
No. 30	12-30	16-37
No. 50	6-17	5-20
No. 100	0-7	0-7
No. 200	0-3	0-3

Aggregate larger than and retained on the No. 8 sieve, when combined, shall have a maximum of 10% crushed particles when tested in accordance with California Test 205. Fine aggregate shall consist of natural sand only.

Aggregate absorption shall not exceed 1% and the amount of moisture in the aggregate, when mixed with the resin, shall not exceed 1/2 of the aggregate absorption as determined by California Test 226.

Sufficient material to produce minimum of one cubic foot of concrete shall be furnished to the engineer, at least 15 working days prior to placement. The material will be sent to the Transportation Laboratory to determine the specific mix design and yield.

Each shipment of polyester styrene and high molecular weight methacrylate resin shall be accompanied by a Material Safety Data Sheet (MSDS) and a Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications certifying that the material conforms to the requirements of these special provisions.

One quart of the resin from each lot to be used shall be sampled at the job site and submitted to the Transportation Laboratory a minimum of five working days prior to use.

PREPARE CONCRETE SURFACE - Surfaces shall be prepared as specified in "Remove Concrete Deck Surfaces" of these specifications.

APPLY PRIME COAT - Prime coat consisting of high molecular weight methacrylate shall be applied prior to placing the polyester concrete.

The area to receive the prime coat shall be visibly dry and the surface temperature shall be between 50°F and 100°F when the prime coat is applied. Methods proposed to artificially heat the surface to meet these requirements are subject to the approval of the engineer.

The promoter/initiator added to the prime coat shall be determined by the contractor to produce a gell time, on the concrete surface, of not less than 45 minutes at the time of application.

Machine application of the prime coat resin may be performed by using a two-part resin system utilizing a promoted resin for one part and an initiated resin for the other part. The pressure at the spray nozzle shall not be great enough to cause appreciable atomization of the resin. Compressed air shall not be used to produce the spray.

The deck surfaces shall be flooded with the prime coat resin, allowing penetration into the concrete and filling of all cracks. The quantity of initiated, promoted resin shall be limited to five gallons at a time for manual application. A noticeable increase in viscosity prior to placement shall be cause for rejection. The treatment shall be applied within five minutes after complete mixing. Excess material shall be redistributed by squeegee or brooms within five minutes after application. Prime coat application rate shall not exceed 120 SF/gal.

Before the prime coat resins hardens, imperfections or spalls with standing liquid shall be filled with commercial quality concrete or sandblast sand, and finished to a uniform surface. The sand shall have a maximum moisture content of less than 0.5 of the aggregate absorption, when tested in accordance to California Test 226.

MIXING - Polyester styrene concrete shall be mixed in mechanically operated mixers. The polyester resin binder in the concrete shall be approximately 12% by weight of the dry aggregate. The exact percentage will be determined by the engineer.

The percent of peroxide initiator shall result in a concrete set time greater than 40 minutes but not greater than four hours.

The resin binder shall be initiated and thoroughly blended prior to introduction of aggregate to the binder. The polyester concrete shall be mixed a minimum of two minutes prior to placing. A continuous mixer, employing an auger screw/chute device, shall be approved by the engineer upon demonstrating its ability to produce a satisfactory product.

PLACING - Polyester styrene concrete shall be placed and finished prior to gelling or within 15 minutes following initiation, whichever occurs first. Polyester concrete that is not placed within this time shall be discarded.

The polyester styrene concrete shall be consolidated to a relative compaction of not less than 97%, as determined by the engineer using California Test 552.

Expansion joints shall be adequately isolated prior to overlaying.

JOINT SEAL - Joint seal shall conform to the details shown on the plans and the provisions in Section 51-1.12, "Expansion and Fixed Joints and Bearings," of the Standard Specifications and elsewhere in these special provisions.

FINISHING - Finishing shall conform to the requirements of Section 51-1.17 of the Standard Specifications and the following: Finishing equipment used shall strike off the polyester styrene concrete to the established grade and cross section. Finishing equipment shall be fitted with vibrators or other means of consolidating the polyester concrete to the required compaction.

Drawings showing details of the working parts of all equipment used for strike-off and consolidation shall be provided by the manufacturer for review, 15 days before use if requested by the engineer.

Polyester styrene concrete surfaces shall receive an abrasive sand finish. The sand shall be a commercial blast sand conforming to the aggregate dryness requirements of these special provisions and the following grading limits:

Sieve Sizes	Percentage Passing
No. 8	100
No. 30	0

The abrasive sand finish shall be applied immediately after overlay strike-off. Sand shall be broadcast onto the surface before gelling occurs to effect a uniform coverage of 0.4 to 0.8 pounds per square yard.

Polyester styrene concrete overlay shall be protected from moisture, traffic, and equipment for a minimum of two hours following the final concrete set time.

Trial overlay slabs shall be placed on previously constructed concrete bases, prior to constructing the finished overlays. Trial slabs shall be 12 feet wide by six feet long and the same thickness as the overlay to demonstrate the effectiveness of the mixing, placing, finishing equipment and procedures.

All materials used in the trial slabs, including the concrete base, shall become the property of the contractor and shall be removed and disposed of as provided in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

MEASUREMENT - Polyester styrene concrete will be measured at the mixer by volume in cubic feet and shall be computed as the total weight of the batch in pounds divided by the unit weight of the concrete in pounds per cubic foot. The total weight of the batch shall be calculated as the sum of all materials, including hardeners/initiators, entering into the batch. The contractor shall furnish suitable measuring devices to assure adequate proportioning of the materials and accurate measurements for calculating pay quantities. The pay quantity shall be the quantity actually used in the work, exclusive of wasted or unused material.

The yield will be determined by measuring the unit weight of the fresh concrete in a nominal 0.25 cu ft calibrated container, using procedures similar to those in ASTM C138, "Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete."

PAYMENT - Furnishing the polyester concrete will be paid for at the contract price per cubic foot for furnish overlay concrete and shall include full compensation for furnishing polyester resin binder, promoter/hardeners, initiators and aggregate.

Placing the polyester concrete will be paid for at the contract price per square foot for polyester concrete overlay. The contract price shall include full compensation for furnishing all labor, materials for abrasive sand finish prime coat, tools, equipment and incidentals, and for doing all the work involved in constructing the overlay complete in place, including wash station, application of prime coat, abrasive sand finish, and furnishing, constructing and disposing of trial overlays and base, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the engineer.

Specification for High Molecular Weight Methacrylate (HMWM) Polymer Concrete Overlay

MATERIALS - HMWM polymer concrete overlay shall conform to the details shown on the plans and the requirements of these special provisions.

Prior to constructing the HMWM polymer overlay, the contractor shall arrange to have the material supplier furnish (1) technical service relating to the application of material and (2) health and safety training for personnel who are to handle the HMWM concrete and prime coat.

Cleaning and flushing of equipment, tools, etc., shall be done with an appropriate solvent, as approved by the engineer, in such a manner to minimize personal and environmental hazards. A soap and water wash station shall be provided for the workers at the job site.

Concrete shall be a low-fuming methacrylate resin and graded concrete aggregate. The resin shall be a High Molecular Weight Methacrylate resin meeting the following requirements:

High Molecular Weight Methacrylate Resin

Viscosity:	<25 cp (Brookfield RVT W/UL Adaptor, 50 RPM @ 77°F)	ASTM D-2393
Specific Gravity:	1.01 to 1.10 @ 77°F	ASTM D-2849
Flash Point:	>180°F	ASTM D-3278
Vapor Pressure:	<1.0 mm Hg @ 77°F	ASTM D-323
PCC Saturated Surface Dry Strength	500 psi, minimum	Calif. Test 551
Tack-Free Time	400 minutes max.	Calif. Test 551

The catalyst system shall be a metal dryer and peroxide. The promoter and initiator, if supplied separate from the resin, shall not contact each other directly. Containers of peroxide and the metal dryer will not be stored together in a manner that will allow leakage or spillage from one to contact the containers or material of the other. Alternate catalyst systems are subject to approval by the engineer.

Aggregate for HMWM polymer concrete shall consist of approximately 12% fly ash or portland cement, 44% fine aggregate and 44% coarse aggregate. The aggregates shall conform to the quality requirements of Section 90-2.02, "Aggregates," of the Standard Specifications and shall be within the following grading limits:

Combined Aggregate

Sieve Size	% Passing
3/8"	100
No. 4	60-77
No. 8	45-62
No. 100	13-17
No. 200	12-15

Aggregate retained on the No. 4 and No. 8 sieves, when combined, shall have a maximum of 10% crushed particles when tested in accordance with California Test 205. Fine aggregate shall consist of natural sands and portland cement or fly ash. Fly ash shall not exceed 4% ignition loss as determined by ASTM C618.

Aggregate absorption shall not exceed 1% and the amount of moisture in the aggregate, when mixed with resin, shall not exceed 1/2 of the aggregate absorption as determined by California Test 226.

The HMWM binder in the concrete shall be approximately 8.0% by weight of the dry aggregate. The exact percentage will be determined by the engineer. The contractor shall furnish to the engineer at least 15 days prior to placement, an amount of material sufficient to produce a minimum of one cubic foot of concrete.

A Certification of Compliance conforming to the provisions in Section 6-1.0-7, "Certificate of Compliance," of the Standard Specifications and a Material Safety Data Sheet (MSDS) shall be furnished for each shipment of high molecular weight methacrylate resin certifying that the material conforms to the requirements of these special provisions. In addition, at least one quart of the resin from each lot shall be sampled at the job site and submitted to the Transportation Laboratory a minimum of five working days prior to use.

SURFACE PREPARATION - Concrete surfaces shall be prepared as specified in "Remove Concrete Deck Surfaces" of these specifications.

APPLY PRIME COAT - The prime coat shall consist of the same HMWM resin used as the concrete binder. The prime coat shall be uniformly applied immediately ahead of the methacrylate concrete in a manner to completely cover the existing surface with no dry areas or ponding. The rate of spread shall be one gallon per 10 to 15 square yards of surface; the exact rate will be determined by the engineer. If the prime coat resin becomes contaminated before concrete placement, the resin shall receive an additional abrasive blast cleaning and an additional prime coat of fresh resin shall be applied.

The mix of promoted resin shall be initially limited to five gallons at a time. Larger volumes may be used if approved by the engineer. Any significant increase in viscosity prior to placement shall be cause for rejection.

The surface temperature of the existing pavement shall be 40°F or above when primer is placed, and shall be dry for a minimum period of 12 hours prior to placing the primer.

Machine application of the prime coat resin may be performed by using a two-part resin system utilizing a promoted resin for one part and an initiated resin for the other part. The pressure at the spray-nozzle shall not be great enough to cause appreciable atomization of the resin. Compressed air shall not be used to produce the spray.

POLYMER CONCRETE -

Mixing - The catalysts shall be thoroughly mixed into the resin before adding aggregate. Mixing time will be a minimum of two minutes after introduction of resin and aggregates. Water shall not be allowed to contact the HMWM concrete at any time during the mixing, placing, or finishing of overlay.

Placing - The methacrylate polymer concrete shall be placed within 15 minutes after mixing. The contractor shall adjust the addition of the promoter/initiators to produce a concrete set timed between 30 and 180 minutes at the time of placement.

Overlay thickness shall not exceed two inches without approval by the engineer.

The HMWM polymer concrete shall be consolidated to a relative compaction of not less than 97%, as determined by the engineer using California Test 552.

Finishing - The finished surface shall be smooth without irregularities.

Finishing shall conform to the requirements of Section 51-1.17 of the Standard Specifications and the following:

Finishing equipment shall be capable of striking off the concrete to the established grade in such a manner to achieve enough compaction to cause resin to flush to the surface. The equipment may require a shuttling, vibrating, spinning, or combination of these methods to provide satisfactory results.

Drawings showing details of the working parts of all equipment used for strike-off and consolidation shall be provided by the manufacturer for review, 15 days before use if requested by the engineer.

The HMWM overlay shall be protected from moisture, traffic, and equipment for a minimum of four hours following the final concrete set time.

Texturing

HMWM polymer concrete surfaces shall receive an abrasive sand finish. The sand shall be a commercial blast sand conforming to the dryness requirements of these special provisions and the following grading limits:

Sieve Sizes	Percentage Passing
No. 8	100
No. 30	0

The abrasive sand finish shall be applied by mechanical means immediately after overlay strike off. Sand shall be broadcast onto the surface before gelling occurs to effect a uniform coverage of 0.4 to 0.8 pound per square yard.

EXPANSION JOINTS - Expansion joints and fixed joints shall be adequately isolated prior to overlaying. Joint seal shall conform to the details shown on the plans and the provisions in Section 51-1.12, "Expansion and Fixed Joints and Bearings," Standard Specifications and elsewhere in these special provisions.

Trial overlay slab shall be placed on previously constructed concrete bases prior to constructing the finished overlays. Trial slab shall be 12 feet wide by 6 feet long and the same thickness as the overlay to demonstrate the effectiveness of the mixing, placing, finishing and texturing equipment and procedures.

All materials used in the trial slabs, including the concrete base, shall become the property of the contractor and shall be removed and disposed of as provided in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Measurement - High Molecular Weight Methacrylate polymer concrete overlay will be measured by the cubic foot at the mixer. The volume to be paid for will be determined by the engineer from calculations based on the amount of resin used and the yield. The contractor shall furnish suitable measuring devices to assure adequate proportioning of the materials and accurate measurement for pay quantities. The pay quantity shall be the quantity actually used in the work, exclusive of wasted and unused material or material placed in excess of the dimensions shown on the plans.

The yield will be determined by measuring the unit weight of the fresh concrete in a nominal 0.25 cu ft calibrated container, using procedures similar to those in ASTM C138, "Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete."

Payment - The contract price paid per cubic foot for High Molecular Weight Methacrylate Polymer Concrete Overlay shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals involved in constructing the overlay including primer, any necessary grinding, wash station, sand cover, joint preparation, and surface preparation as shown on the plans, and as provided in the Standard Specifications and these special provisions, and as directed by the engineer.

Specification for HMWM Bridge Deck Treatment

Concrete surfaces of bridge decks shall be treated with a penetrating sealer in accordance with the requirements of these special provisions.

The surfaces to be treated include:

The following bridges shall be treated:

The work to be done includes preparing surfaces and furnishing and applying treatment material.

Concrete surfaces shall be prepared by manual, air or power sweeping the entire deck surface to be treated and blowing all loose material from visible cracks using high pressure air. All traces of asphaltic or petroleum products and concrete curing seals shall be removed by abrasive blasting prior to air sweeping.

The material used for treating the concrete shall be a low viscosity, nonfuming, high molecular weight methacrylate resin conforming to the following:

HIGH MOLECULAR WEIGHT METHACRYLATE RESIN

Viscosity:	Less than 25 cp (Brookfield RVT w/UL adaptor 50 RPM @ 77°F)	ASTM D-2393
Specific Gravity:	1.01 to 1.10 @ 77°F	ASTM D-2849
Flash Point:	Greater than 180°F	ASTM D-3278
Vapor Pressure:	Less than 1.0 mm Hg @ 77°F	ASTM D-323
Tact Free Time	400 minutes maximum	Calif. Test 551
PCC Saturated Surface Dry Bond Strength	500 psi minimum @ 24 hrs.	Calif. Test 551

A compatible promoter/initiator system shall be capable of providing a resin gel time of not less than 40 minutes nor more than 1 1/2 hours at the temperature of application. Gel time shall be adjusted to compensate for the change in temperature throughout treatment application. The temperature of the surfaces to be treated shall range from 40°F to 120°F. The contractor shall arrange to have a technical representative on-site to provide mixing proportions, equipment suitability, and safety advice to the contractor and engineer.

The promoter and initiator, if supplied separate from the resin, shall not contact each other directly. Containers of promoters and initiators shall not be stored together in a manner that will allow leakage or spillage from one to contact the containers or material of the other.

A Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications and a Material Safety Data Sheet (MSDS) shall be furnished for each shipment of high molecular weight methacrylate resin certifying that the material conforms to the requirements of these special provisions. In addition, at least one quart of the resin shall be sampled at the job site and submitted to the Transportation Laboratory a minimum of five working days prior to use.

Machine application of the resin may be performed by using a two-part resin system utilizing a promoted resin for one-part and an initiated resin for the other part. The pressure at the spray nozzle shall not be great enough to cause appreciable atomization of the resin. Compressed air shall not be used to produce the spray.

The rate of application of promoted/initiated resin shall be approximately 100 square feet per gallon; the exact rate shall be determined by the engineer. The surface to be treated shall be visibly dry and above 40°F prior to resin application.

The deck surfaces shall be flooded with resin, allowing penetration into the concrete and filling of all cracks. The quantity of initiated, promoted resin shall be limited to five gallons at a time for manual application. A significant increase in viscosity prior to proper penetration shall be cause for rejection. The treatment shall be applied within five minutes after complete mixing. Excess material shall be redistributed by squeegee or brooms within five minutes after application. The entire treated area of the bridge deck shall have sand broadcast by mechanical means to effect a uniform coverage of .25 to .30 pounds per square yard. The sand shall be a uniformly graded aggregate conforming to the quality requirements of Section 90-2.02, "Aggregates," of the Standard Specifications and shall conform to the following limits for grading:

Sieve Size	% Passing Max.
No. 4	100
No. 8	90-100
No. 20	5-10
No. 50	0-5

It is the intention of this specification to allow the use of commercially available blast sands of No. #8/20, applied by a common lawn broadcast type seeder/spreader. Sand shall be placed 10 to 15 minutes after the resin has been applied and before any gelling of the resin occurs.

Before the resin hardens, imperfections or spalls with standing liquid shall be filled with commercial quality concrete or sandblast sand, and finished to a uniform surface. The sand shall have a maximum moisture content of less than 0.5 of the aggregate absorption, when tested in accordance to California Test 226.

Traffic shall be permitted on the treated surface when the sand cover adheres sufficiently to resist brushing by hand.

Vertical and overhead surfaces to be treated shall be hand cleaned to remove loose material and shall receive two brush or roller applications applied at least one hour apart.

Solvent for cleaning and flushing of equipment, tools, etc., shall be used in such a manner to minimize personal and environmental hazards as approved by the engineer. A soap and water wash station shall be provided for the workers at the job site.

Treating bridge deck or vertical surfaces will be measured by the square foot based on plan dimensions and will be paid for as HMWM bridge deck treatment.

Furnishing the high molecular weight methacrylate resin will be measured by the gallon of mixed material actually placed and will be paid for as furnish HMWM bridge deck treatment material. No payment will be made for material wasted or not used in the work.

The contract price paid per square foot for HMWM bridge deck treatment shall include full compensation for furnishing all labor, materials (except treatment material), tools, equipment and incidentals, and for doing all the work involved in preparing concrete surfaces and applying treatment material as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the engineer.

The contract price paid per gallon for furnished HMWM bridge deck treatment material shall include full compensation for furnishing all labor, materials, including catalysts, tools, equipment and incidentals necessary to furnish the bridge deck treatment material to the site of the work, ready for application, as specified in the Standard Specifications and these special provisions and as directed by the engineer.

Specification for Polyester Styrene Resin Seal Coat

Description - The work shall consist of an application of binder and a cover of dry screenings applied to PCC as specified in these specifications to provide a skid resistant surface.

The type of seal coat to be applied will be designated on the plans or specified in the special provisions.

The rates of application for the screenings and binders for the various types of seal coats shall be within the ranges specified in the following table. The exact rates will be determined by the engineer.

Seal Coat Types	Size of Screenings	Rate of Application per Square Yard: Screenings (pounds)	Rate of Application per Square Yard: Binder (pounds)
Fine	1/4" x No. 10	12 to 20	2.8 to 3.6
Medium Fine	5/16" x No. 8	16 to 22	2.8 to 3.6

Materials: Binder shall consist of thermoset polyester resin consisting of unsaturated isophthalic polyester dissolved in styrene, using metallic soaps and peroxides to initiate polymerization. Properties of the polyester-styrene polymer shall be as follows:

Viscosity, Brookfield RVT No. 3, 50 RPM @ 77°F	600-1200 cps	ASTM D-2393
Specific Gravity	1.13-1.15	ASTM D-2849
Gel Time @ 77°F (150 ml)	10-15 minutes	Calif. Test 434

Cured Unfilled Resin:

Tensile Strength; PSI	2000-4000 ASTM D-638
Elongation, %	45-65 ASTM D-638
Conditioning, 18h/23°C/50% + 5h/70°C	ASTM D-618
Heat Distortion	Yields

The above resin shall also contain 0.5% silane coupler, based on the weight of the polyester-styrene polymer. The silane shall be gamma-methacryloxypropyltrimethoxysilane.

Catalyst system shall be determined by the manufacturer of the resin to accommodate the method of mixing and applying promoted resin.

7 Manually mixed and applied methods shall have the hardener (usually Cobalt Octoate or Cobalt Naphthenate) incorporated in the resin as received from the manufacturer. Prior to applying this system, an initiator (usually methylethyl ketone peroxide - MEKP) shall be thoroughly mixed into the resin and then promptly applied. Resin may be applied by mechanical spray equipment at the option of the contractor.

7A Resin shall be applied by mechanical spray apparatus.

The contractor's equipment for mixing and applying resin by mechanical means shall be compatible with the resin supplied. Air atomization shall not be allowed.

- Edit para. 7 if resin must be spray applied.
- Edit para. 7A if resin may be manually applied.

The peroxide shall be injected or introduced to the promoted resin flow in such a manner as to effect thorough blending of promoted resin and peroxide. The peroxide unit shall be capable of injecting from 1/2% to 2 1/2% peroxide to volume of resin within an accuracy of 10%. The volume of peroxide may be varied by the operator from time to time as field conditions warrant. The peroxide unit shall have a flow sensing unit to provide a warning in the event of peroxide flow loss below the volume setting. The sensing unit shall activate a resin cut-off valve or a sounding device.

Two-component mixing may be done by promoting 1/2 of the resin with the metal dryer and the other half with the peroxide if recommended by the resin manufacturer and approved by the engineer.

Screenings shall conform to the following requirements prior to depositing on the roadbed:

Screenings shall consist of broken stone, crushed gravel, or both. At least 50% by weight of the screenings shall consist of crushed particles as determined by California Test 205.

Screenings shall be clean, dry, and free from dirt and other deleterious substances, such as oils.

The percentage composition by weight of screenings shall conform to one of the following gradings when determined by California Test 202:

	Percentage Passing	
	Med. Fine 5/16" x No. 8	Fine 1/4" x No. 10
Sieve Sizes		
3/8"	100	100
No. 4	30-60	60-85
No. 8	0-15	0-25
No. 16	0-5	0-5
No. 30	0-3	0-3
No. 200	0-2	0-2

Screenings shall also conform to the following quality requirements:

Tests	California Test	Requirements
Loss in Los Angeles Rattler (after (100 revolutions)	211	10% Max.
Loss in Los Angeles Rattler (after 500 revolutions)	211	40% Max.
Cleanness Value	227	85 Min.

The moisture content of the aggregates shall not exceed 1/2 of the percentage of aggregate absorption at the time of applying the cover material when tested in accordance with California Test 226.

Maintaining Traffic - At locations where public traffic is being routed over a surface upon which a seal coat is to be applied, the seal coat shall not be applied to more than 1/2 the width shall be kept free of obstructions and open for use by public traffic until the seal coat first applied is ready for use by traffic.

The contractor shall provide for the passage of public traffic through the work in accordance with the provisions in Sections 7-1.08, "Public Convenience," and 7-1.09, "Public Safety," and when directed by the engineer, traffic shall be routed through the work under one-way control.

Preparation for Seal Coats - Immediately before applying the binder, the surface to be sealed shall be clean and dry.

Chlorinated rubber curing compound and asphaltic products, oil, or other contaminants that may diminish bond capacity shall be abrasively removed. Cleaning, prior to applying seal coat, shall be done by power sweeping or with compressed air, in such a manner to avoid obstructing traffic visibility or creating a general nuisance.

Applying Binder - Manual mixing shall be limited to five gallon volumes, or as permitted by the engineer. Machine mixing and application shall be done in accordance to the resin manufacturer's recommendation.

Binder shall not be spread when weather conditions are unsuitable. Seal coats requiring screenings shall not be applied until sufficient screenings are on hand to immediately cover the binder, or when the atmospheric temperature or pavement temperature is below 50°F.

The resin shall be initiated for a minimum open time of 15 minutes before a significant increase in viscosity occurs as applied.

Gel time of the resin may be adjusted by altering the percent of peroxides added but shall not be less than the minimum percent recommended by the resin manufacturer. Gel times may also be altered by adding accelerators or inhibitors. Premature setting of the resin, prior to placing cover material, shall be recoated at the contractor's expense. The seal coats shall be applied in such a manner that the joint between lanes shall present a neat and uniform appearance.

For daylight work, spreading binder shall be discontinued sufficiently early in the day to permit the termination of traffic control prior to darkness.

Binder shall not be spread a greater distance than can be immediately covered by screenings, unless otherwise permitted by the engineer.

Binder spread by machine methods shall have the cut off of binder made on building paper or similar material spread over the surface. Paper shall also be placed over the treated surface for a sufficient length at the beginning of a spread so that the nozzles are spreading properly when the uncovered surface is reached. The building paper shall then be removed and disposed of in a manner satisfactory to the engineer. Traffic lines, markings and expansion joints shall be protected from contamination by the binder in a manner satisfactory to the engineer.

The distribution of binder shall not vary more than 15% transversely nor more than 10% longitudinally from the specified rate of application as determined by California Test 339.

Spreading Cover Material - Immediately following the application of the binder, it shall be covered with screenings spread within 10% of the required rate per square yard. Excess screening shall not be allowed. Screening coverage should not be greater than one particle in thickness.

Screenings shall be spread by means of a self-propelled chip spreader, equipped with a mechanical device which will spread the screenings at a uniform rate over the full width of the treated area in one application. The joint between adjacent applications of screenings shall not coincide with the lane wheel tracks.

Operating the chip spreader at speeds which cause the chips to roll over after striking the resin covered surface will not be permitted. Chip spreader or contractor's equipment shall not be allowed on resin seal coat after five minutes has elapsed from the time of placing resin and screenings.

The transverse cut off of screenings shall be complete and any excess screenings shall be removed from the surface prior to resuming operations.

Stockpiling of screenings prior to placing will be permitted, however, any contamination resulting during storage or from reloading operations will be cause for rejection.

Finishing - After the screenings have been spread upon the binder, any piles, ridges, or uneven distribution shall be carefully removed to insure against permanent ridges, bumps or depressions in the completed surface.

Traffic will not be permitted to travel over seal coats until binder has sufficiently hardened to resist removing screenings with fingers. The exact time will be determined by the engineer.

The contractor shall provide the necessary equipment and flagmen required by the engineer to control traffic in accordance with the provisions in Sections 7-1.08, "Public Convenience," and 7-1.09, "Public Safety."

Power brooming shall be performed to remove loose screenings prior to the end of each day's work. The exact time of brooming will be determined by the engineer. Any excess screenings shall be removed from all paved areas. Sweeping or brooming of seal coat surfaces shall be performed in such a manner that the screenings set in the binder will not be displaced. Excessive brooming will not be permitted.

When directed by the engineer, excess screenings shall be salvaged and stockpiled at designated locations.

Excess screenings which in the opinion of the engineer are not salvageable and which interfere with drainage shall be removed and disposed of by the contractor at his expense. The removed screenings shall be disposed of in accordance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," or at other suitable locations if permitted by the engineer.

The completed surface shall present a uniform appearance, free from ruts, humps, depressions, or irregularities due to an uneven distribution of binder or screenings. Appropriate "Loose Gravel" signs shall be posted for 24 hours after traffic is allowed on chip seal.

Measurement - Quantities of screenings to be paid for by the ton or cubic yard of net screening adhered to the seal coat and will be determined as provided in Section 9-1.01, "Measurement of Quantities." When paid for by the cubic yard, screenings will be measured in the vehicle at the point of delivery.

Quantities of polyester binder to be paid will be determined by the actual quantity of resin used measured by gallon or pound. Quantities of polyester binder wasted or disposed of in a manner not called for under the specification, or remaining on hand after completion of the work, will not be paid for.

Payment - Seal coat shall be paid for at the contract price per ton or cubic yard for screenings, whichever unit is designated in the contract item, and the contract price per pound or gallon of polyester binder, whichever unit is designated in the contract item, for whatever items are provided and involved. Such prices shall include preparation for seal coat and furnishing and applying binder and screenings.

The above prices and payments shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in applying seal coat, complete in place, as shown on the plans, and as specified in these specifications, and as directed by the engineer.

Salvaging and stockpiling excess screenings will be paid for as extra work as provided in Section 4-1.03D.

Specification for Pavement Subsealing (Silicone Foam)

Existing concrete pavement, at locations shown on the plans, shall be pressure-injected with silicone foam, in accordance with these special provisions. Pressure-injecting concrete pavement consists of filling voids under pavement slabs, to prevent migration of fines across pavement joints. Pressure-injection shall consist of drilling holes in pavement slabs and injecting silicone foam materials.

The silicone foam shall be liquid two component RTV Silicone foam. The material shall be furnished in two components which when combined in equal volumes, will react to create a foam. The two silicone components will be referred to by the letter designations, A and B. The silicone resin shall meet the following requirements:

Specific Gravity (A & B)	1.10 - 1.20
Set Time (minutes) combined	15 - 20 at 77°F
Viscosity (A) (Brookfield, 10 rpm, #2 spindle, 77°F)	15 - 35 poise
Viscosity (B) (Brookfield, 10 rpm, #2 spindle, 77°F)	15 - 35 poise
Stability (A & B)	12 months (dark at 77°F)
Free foam density (lbs/ft3)	20 - 35
Closed cell structure	60% minimum
Water absorption (ASTM D-1056, by weight)	10% maximum

The materials shall be shipped in their original, tightly sealed containers or unopened packages, all clearly labeled with the manufacturer's name, product identification, lot numbers and the manufacturer shall provide a material safety data sheet (MSDS).

Materials shall be stored indoors in their original containers at a temperature not to exceed 80°F until ready for use.

Automatic mixing and injection equipment shall have two separate, agitated supply tanks, clearly marked for components A and B. Prior to use, the A and B components shall be stirred individually. A plural component injection nozzle shall combine and thoroughly mix components, in a 1:1 volume ratio, from supply tanks A and B. The injection equipment shall be capable of maintaining an injection-pressure of up to 100 psi. The injection equipment shall be capable of measuring the volume of resin injected per hole to an accuracy of 10%.

Each injection hole shall be drilled without the use of water and shall be of the proper size to accommodate equipment used for injection. The injection hole shall be drilled from the top of pavement through the treated base. The size of the hole shall not be less than one-inch nor more than two inches in diameter. Care shall be taken not to damage the pavement surface adjacent to the holes.

Holes shall be drilled one foot down traffic from the joint and 2.5 and 8.5 feet from the shoulder, or as shown on the plans. Before commencing pressure-injection, the contractor shall have, and maintain, a minimum of two consecutive predrilled slabs in advance of the pressure-injection operation. The hole furthest from the shoulder shall be injected first and completed before injecting hole nearest shoulder. When silicone foam appears at a joint, crack, or an adjacent drill hole, injection shall cease.

A minimum of 1.0 gallon and a maximum of 1.3 gallons per joint shall be injected unless otherwise directed by the engineer. Approximately equal volumes shall be injected in each hole. Working cracks shall be treated as a joint.

Pressure-injection shall not be performed when the air temperature is below 45°F, the subgrade material is frozen, or during inclement weather.

In the event the engineer determines that continued injection at any specific location is no longer feasible, he may direct the contractor to cease injection at that location. Measurement and payment for performance of work at any such locations, where work has been discontinued, will be made at the contract prices for the items involved, on the basis of the amount of work completed.

The contractor shall take necessary precautions to prevent silicone foam from being pumped or disposed of into any drainage or other open structure.

Excess silicone foam protruding from the injection holes shall be cut flush with the pavement surface and disposed of at contractor's expense.

At the end of each shift, the work area shall be left in a cleanly swept and neat condition.

MEASUREMENT AND PAYMENT - Drilling holes (subsealing-silicone foam) will be measured as units, by actual count in the field.

Silicone foam (subseal) will be measured by the gallon of combined components A and B, used in the work.

The contract unit price paid for drilling hole (subsealing silicone foam) and the contract price paid per gallon for silicone foam (subseal) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in drilling each hole and injecting silicone foam respectively, including removing surplus cured silicone and disposing of the residue and empty material containers, as specified in the Standard Specifications and these Special Provisions, and as directed by the engineer.

CALIFORNIA TEST METHODS

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Office of Transportation Laboratory
P. O. Box 19128
Sacramento, California 95819

California Test 550
August 1984

METHOD FOR DETERMINING THE SURFACE ABRASION RESISTANCE OF CONCRETE SPECIMENS

SCOPE

The surface abrasion test measures the ability of a concrete specimen to resist surface abrasion by impact of steel balls in the presence of water.

PROCEDURE

A. Apparatus

1. A mechanical shaker capable of agitating a mold assembly containing the test specimen, water, and steel balls, in a vertical direction at 1200 cycles per minute with a 1-inch stroke (see Figure 1).

2. 1—steel test mold, 4 inches diameter by 5 inches high, fitted with a watertight base and cover. A ⅛" steel ring, triangular in cross-section and inserted to form a lip, encircles the mold interior 2 inches above the bottom and combines with the base to hold the sample in place and protect the vulnerable edges of the specimen (see Figure 2).

3. 8 chrome steel balls, 13/32 inch diameter, weighing 4.5 ±0.3 grams each. Total weight of the 8 balls shall be between 32 and 38 grams.

4. 1—200 ml graduated cylinder.

5. Balance, capacity 5,000 grams sensitive to 1 gram.

B. Specimens

The test specimens shall be cylindrical in shape, 4.0 inches in diameter and 2.0 inches high, and may be either cores cut from hardened concrete or molded specimens. They shall be soaked in water for a minimum of 2 hours prior to testing.

C. Test Procedure

1. Surface dry the specimen, weigh, and record weight to the nearest gram.

2. Place specimen in the test mold with the surface to be tested facing up. Place the mold with specimen on the test mold base and add 8 steel balls and 200 ml of water. Attach the cover and clamp the assembly to the mechanical shaker.

3. Agitate the assembly at 1200 ±10 cycles per minute for 3 minutes ±5 seconds and remove from the mechanical shaker.

4. Remove the specimen from the test mold. Flush off the abraded material, dry the surface, weigh, and record weight to the nearest gram.

D. Calculations

The abrasion loss in grams is calculated by subtracting the weight of the surface dry specimen after the test from the weight of the surface dry specimen before test.

REPORTING OF RESULTS

Report the amount of abrasion loss in grams. The age of the concrete shall be included in the report.

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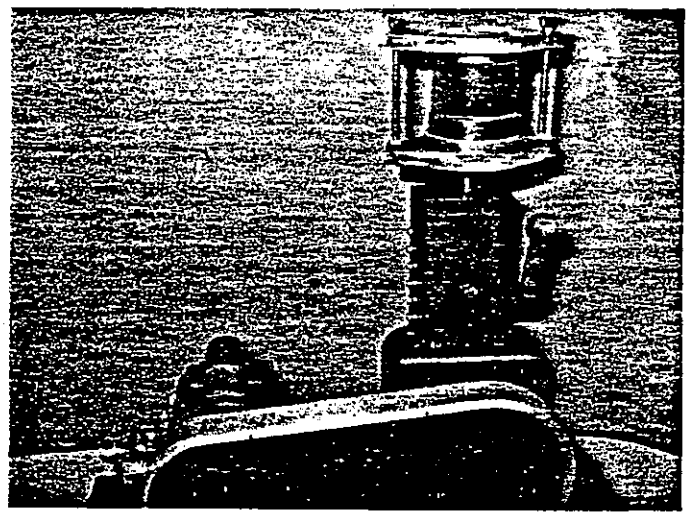
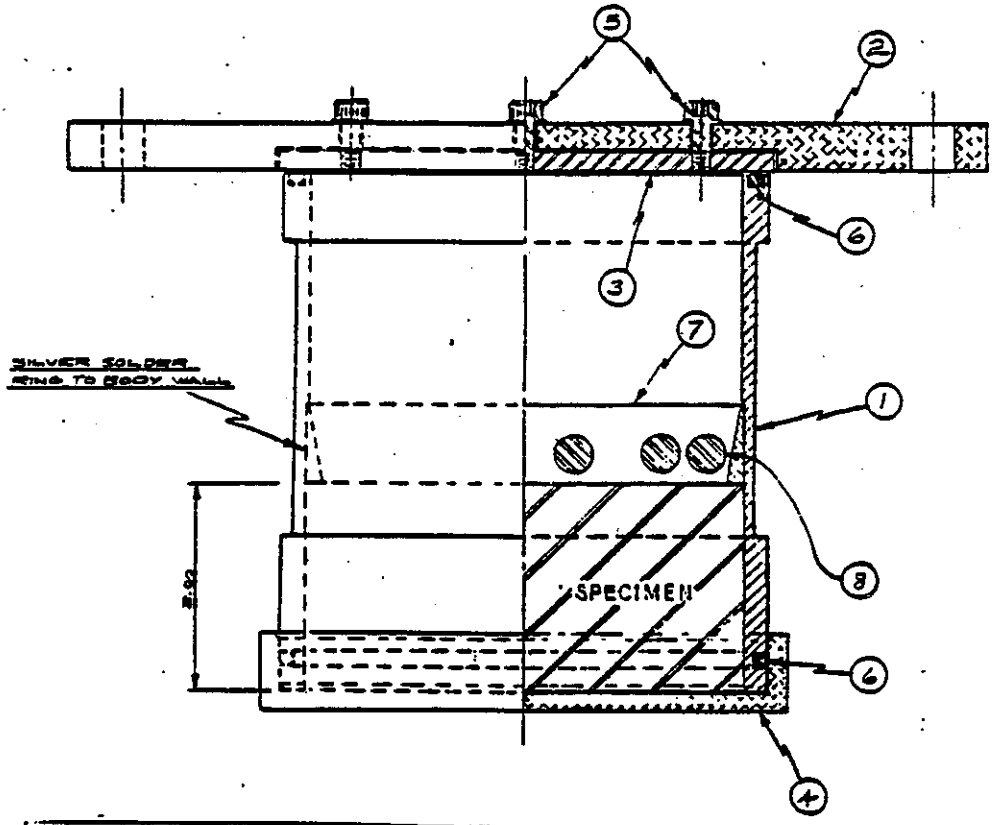


Figure 1—Mechanical Shaker



NO. REQ.	PART NO.	DESCRIPTION	STOCK SIZE	MATERIAL	REMARKS
5	9	BALL BEARINGS	1 3/16" DIA x 4.5 OH WEIGHT	STEEL	
1	7	RETAINING RING	4140 STEEL		
2	6	"O" RING	4 3/16 ID x 4 3/16 OD x 1/8 DIA NEOPRENE		
4	5	CAP SCREWS	10-32NF SOCKET, FILISTER HD		
1	4	BASE	ALUM		
1	3	WEAR PLATE	4140 STEEL		
1	2	COVER	ALUM		
1	1	BODY	MILD STEEL		

LIST OF MATERIAL

Figure 2—Surface Abrasion Test Mold

DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
Office of Transportation Laboratory
P.O. Box 19128
Sacramento, California 95819

California Test 551
April 1988

METHOD OF TEST FOR DETERMINING SUITABILITY OF MATERIALS FOR OVERLAYMENT AND REPAIR OF PORTLAND CEMENT CONCRETE PAVEMENT AND STRUCTURES

A. SCOPE

This method covers the procedures to be used to determine the suitability of organic and inorganic materials to be used for overlay of portland cement concrete pavement or structures or for patching spalls in portland cement concrete. Material set time, compressive strength, flexural strength, bonding strength, chord modulus of elasticity, specific gravity, and absorption are covered. Further testing may be necessary to fully evaluate most materials.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Users of this standard do so at their own risk.

This test method is divided into the following parts.

I. Method of test for determination of compressive strength and flow of concrete overlay and patching materials (using two-inch cube specimens).

II. Method of test for determination of set time of concrete overlay and patching material by Gillmore Needles.

III. Method for fabricating concrete specimens of overlay and patching materials.

IV. Method of test for flexural strength of concrete overlay and patching materials.

V. Method of test to determine the bonding strength of concrete overlay and patching materials to PCC.

VI. Method for fabricating PCC blocks for use in the bond test.

VII. Method of test for chord modulus of elasticity of concrete overlay and patching specimens (compressometer method).

VIII. Method of test for specific gravity and absorption of concrete overlay and patching materials.

PART I. METHOD OF TEST FOR DETERMINATION OF COMPRESSIVE STRENGTH AND OF CONCRETE OVERLAY AND PATCHING MATERIALS (USING 2" CUBE SPECIMENS)

A. SCOPE

This method covers determination of the compressive strength of concrete overlay and patching materials using 2" cube specimens.

B. APPARATUS

1. A balance or scale having a minimum capacity of 5000 grams and sensitive to 1 gram.

2. Specimen molds for the 2-inch cube specimens shall be tight fitting, the molds shall have not more than three cube compartments and shall be separable into not more than three parts. The parts of the molds when assembled shall be positively held together. The molds shall be made of hard metal not attacked by cement mortar. The side of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall be plane surfaces with a permissible variation of 0.005 inch. The distances between opposite faces shall be 2 ±.030 inch.

The height of the molds, measured separately for each cube compartment, shall be 2 ± 0.025 inch. The angle between adjacent interior faces and top and bottom planes of the mold, shall be 90° ± 1° measured at points slightly removed from the intersection of the faces.

3. Mixer, bowl and paddle, an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in ASTM C 305, Sec. 2.1, 2.2, and 2.3.

4. Tamper, a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A Durometer hardness of 80 ± 10. Tamper shall have a cross section of ½ by 1 inch and a convenient length of 5 to 6 inches. The tamping face shall be flat and at right angles to the length of the tamper.

5. Trowel or scraper having a steel blade at least 3 inches wide with a straight edge.

6. Testing machine as specified in ASTM Method

C 109, Section 3.10.

7. Flow table and flow mold, conforming to the requirements of ASTM C 230.

C. TEMPERATURE

1. Temperature of the air in the vicinity of the mixing area, the dry materials, molds, base plates, and mixing bowl shall be maintained between 68° and 77°F (20° TO 25°C).

D. TEST SPECIMENS

1. Three or more specimens shall be made for each period of test specified.

In the case of slow setting materials, typical test periods may be 6, 24, and 48 hours and 7, 14, and 28 days.

For fast setting materials typical test periods may be 1, 2, 3, 6, 24 hours and 28 days.

E. PREPARATION OF SPECIMEN MOLDS

1. Testing portland cement based materials.

Thinly cover the interior and exterior of the assembled molds with a mist of light oil and wipe off any excess.

2. Testing materials containing magnesium phosphates, latex, epoxies, or other polymers.

Cover the interior and exterior of the assembled molds with a mixture of wax and solvent and allow to dry before using. A mixture of one part paste wax dissolved in 2 to 3 parts solvent and applied with a paint brush is satisfactory.

F. PREPARATION OF MATERIALS

General: The variety of materials used in concrete overlay and patching materials is extensive. Care must be taken to avoid contamination of individual components. The hazards of each individual component should be recognized.

1. Temperature—Materials shall be brought to a uniform temperature in the range of 68° to 77°F (20° to 25°C) prior to mixing.

2. Cement or fly ash shall be stored in a dry place, in moisture-proof containers, free from lumps, with 100% passing the #16 sieve.

3. The moisture content of the fine and coarse aggregate shall not exceed one half of the absorption of the aggregate. The SSD aggregate shall be 100% passing the ½ inch sieve. Care should be taken to avoid segregation of aggregate.

4. Water used in mixes shall be potable. The water temperature shall be 70°F to 76°F (21°C to 25°C).

5. Packaged material for testing shall be in unbroken packages. Broken packages may be cause for rejection. Package shall be marked in accordance with ASTM C 928, Section 10.

6. The entire package shall be thoroughly blended prior to taking a representative sample for testing.

7. All packaged patching materials shall be tested neat.

G. PROCEDURE

1. General. Mix the concrete overlay or patching material as specified by the manufacturer in the electric mixer or by hand in a batch of such size to yield 10 percent excess after molding test specimens. Hand-mixing procedures are not applicable to air-entrained mixes or mixes with no measurable slump. Follow the manufacturers recommendations as to the order of addition and mixing times. Materials shall be mixed thoroughly in the time allotted.

2. Determination of Flow. The minimum size of a mix used to determine flow shall not be less than 2000 grams total weight. The Flow-table must be clean and dry. Place the flow mold at the center. Place a layer of the mixed material about 1-inch thick in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Then fill the mold with additional material and tamp as specified for the first layer. Strike off material to a plane surface, flush with the top of the mold, by drawing the straight edge of a trowel, held nearly perpendicular to the mold, with a sawing motion across the top of the mold. Wipe the table top clean and dry, being especially careful to remove any liquid from around the edge of the flow mold. Lift the mold away from the material within 1 minute after completing the mixing operation. Immediately, drop the table through a height of ½ inch, 15 times in 10 seconds.

The flow is the resulting average base diameter of the material mass, measured on at least four diameters at approximately equispaced intervals, expressed as a percentage of the original base diameter. If flow is specified, make trial material mixes with varying percentages of liquid until the specified flow is obtained. Make each trial with fresh mixed material.

When testing materials such as magnesium phosphate, or others that may attack the table top, place a thin sheet of mylar plastic on the table top.

3. Compressive Test Samples. Start molding the specimens within one minute after completion of the mixed batch. Place a one-inch layer of the batch, approximately one half of the depth of the mold, in all of the cube compartments.

Tamp the batch in each cube compartment 25 times with the tamper in a spiral motion making sure that all corners are tamped. The tamping pressure shall be sufficient to ensure uniform filling of the

molds. Tamping shall be completed in each compartment before going on to the next. When the tamping of the first layer in all of the compartments is completed tap the sides of the mold with a rubber mallet or jiggle the mold to remove entrapped air along the sides.

Fill the compartments with the remaining material and tamp as specified for the first layer. Tap or jiggle the mold as before. On completion, the material shall extend slightly above the tops of all the molds. With the trowel or tamper force the batch downward into the mold. Then, for the purpose of leveling the mixed material in the mold, draw the flat side of the trowel with the leading edge slightly raised along the length of the mold. Pressure applied to the trowel should result in a well compacted sample. Cut off the batch mix to a plane surface flush with the top of the mold by drawing the straight edge of the trowel, held nearly perpendicular to the mold, using a sawing motion over the length of the mold. Finish to a smooth surface.

Clean off excess material on the mold.

H. CURING

General. Follow the manufacturer's or originator's recommendations as to the cure and when it shall be applied.

Curing Definitions

1. Dry or Room Cure. The test specimens are left in the molds uncovered in the mixing room in a place free from vibration. The set material in cube form is identified and removed from the mold as necessary. Removed samples shall be kept in the mixing room.

2. Damp Cure. The test specimens are covered with a damp cloth or towel after the initial set. Plastic sheeting can be placed on the damp cloth to retard drying of the cloth. The set material is identified and removed from the mold as necessary. Curing is for the period specified.

3. Moist Cure. Immediately upon completion of molding, place the test specimens in the moist closet or moist room. Keep all test specimens in the molds in the moist closet or moist room with their upper surfaces exposed to the moist air, but protected from dripping water. If the specimens are removed from the molds, keep them on the shelves of the moist closet or moist room for 24 hours, and then immerse the specimens in saturated lime water in storage tanks constructed of noncorroding materials. Keep the storage water clean by changing as required. Remove samples as required for testing.

4. Seal Cure. The test specimens, after initial set, are covered with a liquid membrane-forming compound to retard the loss of moisture during the early hardening period. Samples are kept in the mixing room.

5. Plastic Cure. The test specimens, after initial set, are covered with a sheet of plastic film (polyethylene, vinyl, mylar) to prevent escape of liquid and the effect of air on the specimen material.

The cured material can be removed any time after final set if it can be ascertained that said removal will not damage the specimen. Typically, a safe period is twice the final set time.

I. DETERMINATION OF COMPRESSIVE STRENGTH

1. Moist, Damp and Plastic Cures. Test the specimens immediately after the removal from curing environment. If more than one specimen is removed for testing, keep the remaining specimens covered with a damp cloth until time of testing.

2. Test Age. All test specimens shall be broken within the permissible tolerance prescribed as follows:

Test Age	*Tolerance*
1-2-3 hours	± 5 min.
6 hours	± 10 min.
24 hours	± ½ hour
3 days	± 1 hour
7 days	± 3 hours
28 days	± 12 hours

Intermediate test breaks shall be broken within the tolerance of the earlier specified test age.

3. Wipe each specimen to a surface dry condition, and remove any loose sand grains or incrustations from the faces that will be in contact with the bearing blocks of the testing machine.

4. Apply the load to the specimen faces that were in contact with the true plane surfaces of the mold. Carefully place the specimen in the testing machine below the center of the upper bearing block. Prior to testing each cube, it shall be ascertained that the spherically seated block is free to tilt. Cushioning or bedding materials should not be used except for plastic film (not exceeding 3 mils in thickness) which may be used to protect the bearing surfaces. The load may be applied at any rate, up to one half the expected breaking load. Thereafter apply the load continuously, and without interruption, at the rate of 20,000 lbs. per minute until the specimen fails.

J. CALCULATION

1. Record the total maximum load indicated by the testing machine and calculate the compressive strength in pounds per square inch. If the cross sectional area varies more than 2 percent from the nominal, use the actual area for the calculation of the compressive strength. The compressive strength of

all acceptable test specimens (see Section K) made from the same sample and tested at the same period of time, shall be averaged and reported to the nearest 5 psi.

K. SPECIMENS AND RETESTS

1. In determining the compressive strength, do not consider specimens that are manifestly faulty, or that give strength differing by more than 10 percent from the average of all test specimens made from the same sample and tested at the same period of time. If after discarding specimens or strength values, less than two strength values are left for determining the compressive strength of any given period, make a retest.

2. Reliable strength results depend upon careful observance of all specified requirements and procedures. Erratic results at a given test period indicate that some requirements and procedures have not been carefully observed; for example, improper mixing or poor fabrication of mold specimens. Improper centering of cubes, resulting in oblique fractures or lateral movement of the testing machine head during loading, will often cause lower strength results.

L. REPORTS

The mixing report shall include the following information:

1. The material used identified as bag, lot, receiving number, etc.
2. The amount and order of addition to mix.
3. The date, time, and mixing time.
4. Test operators.
5. Mixer used and by whom.
6. Personnel fabricating specimens.
7. Approximate working time of material.
8. Initial set time.
9. Final set time.
10. Workability of mix and flow percentage.
11. Unusual items such as, odor, heat rise, finishing characteristics, etc.
12. Number of cubes made.
13. Cure.

The testing report shall include the following information:

1. Test specimen identification.
2. Type of cure.
3. Date of test.
4. Test operators.
5. Age at time of test.
6. Area in square inches.
7. Maximum load at failure.
8. Average of test specimens broken to nearest 5 psi.
9. Description of break, if break is abnormal.

REFERENCES

ASTM C 109
ASTM C 192
ASTM C 230
ASTM C 305
ASTM C 928

PART II. METHOD OF TEST FOR DETERMINATION OF SET TIME OF CONCRETE OVERLAY AND PATCHING MATERIAL BY GILLMORE NEEDLES

A. SCOPE

1. This method covers determination of the time of setting of concrete overlay and patching materials by means of Gillmore needles.

B. APPARATUS

1. Gillmore needles, as specified in ASTM C 266.
2. Concrete Cylinder Can Lids. Steel can lids as furnished for use for fabricating PCC compressive cylinders. Approximate inside dimensions are 6 inches in diameter and ⅝ inch in depth.

C. TEMPERATURE

1. Temperature of the air, test material, and the Gillmore needles shall be maintained between 68° and 77°F (20°–25°C).

D. PROCEDURE

1. Molding Test Specimen. From the mixed batch take sufficient material to fill the can lid. With a trowel use sufficient pressure on the mixed material to compact it similar to the density when fabricating 2" compressive cubes. Strike off the mixed material until it is flush with the edge of the lid. Place the lid on a piece of nonconductive material such as bare wood or a dry towel at least ¾" thick in the mixing room.

2. Time of Set Determination. In determining the time of setting, hold the needles in a vertical position and apply lightly to the surface of the sample. Consider the material to have acquired its *initial* set when the material will bear, without appreciable indentation, the initial Gillmore needle. Consider the material to have acquired its *final* set when the material will bear, without appreciable indentation, the final Gillmore needle.

3. PRECAUTIONS—The time of setting is affected by the amount and temperature of the liquid added, the material temperature, and by the temperature and the humidity of the air. A minimum of three tests should be taken at each time interval.

Care must be taken to avoid testing over coarse aggregate particles.

E. REPORTS

1. When reporting the initial and final set time, express the time in minutes. Also record air temperature at time of test.

REFERENCES
ASTM C 266

PART III. METHOD FOR FABRICATING CONCRETE SPECIMENS OF OVERLAY AND PATCHING MATERIALS

A. SCOPE

This method describes the fabrication of concrete overlay and patching material specimens for use in California tests for flexure, bonding, compressive strength, modulus of elasticity, specific gravity, absorption, lineal dimension change and abrasion tests.

B. APPARATUS

1. The concrete mixer, scales, tamping rods, miscellaneous equipment and molds shall conform to ASTM C 192. The internal dimensions of the molds shall be 3 inches by 3 inches by 12 inches. The molds for abrasion specimens shall be approximately 4 inches in diameter by 2 inches deep.

C. TEMPERATURE

1. Temperature can be critical to the setting time of the completed mix and will affect the strength of the material. Temperature of the air in the vicinity of the mixing area, materials, molds, and mixers shall be maintained between 68° and 77°F (20° to 25°C).

2. Some materials may contain toxic or volatile substances that may affect operator's health. Care should be taken to assure adequate ventilation. Material Safety Data Sheets (MSDS) shall be reviewed with employees prior to testing any new material.

D. TEST SPECIMENS

1. The number of specimens and number of test batches are dependent on the amount of available material and the nature of the test program. In general, two or more specimens are made for each test age and test condition unless otherwise specified.

2. For slow setting materials typical test ages are 1, 3, 7 and 28 days.

3. For fast setting materials typical test ages are 3, 6 and 24 hours and 28 days.

E. PREPARATION OF SPECIMEN MOLDS

1. Testing portland cement or gypsum based materials.
   a. Thinly cover the interior and exterior of the assembled molds with a mist of light oil and wipe off excess oil.
2. Testing materials containing magnesium phosphates, latex, epoxies, or other polymers.
   a. Cover the interior and exterior of the assembled molds with a mixture to paste wax and solvent and allow to dry before using. A mixture of one part paste wax dissolved in 2 to 3 parts solvent, such as toluene, and applied with a paint brush is satisfactory.
3. Lineal dimension change molds
   a. After coating the molds with the release agent, place the measuring studs in the endplates, using care to avoid contacting the release agent with the studs.

F. PREPARATION OF MATERIALS

General. The variety of materials used in concrete overlay and patching materials is extensive. Care must be taken to avoid contamination of individual components. The hazards of each individual component should be recognized.

1. Temperature—Materials shall be brought to a uniform temperature between 68 to 77°F (20 to 25°C) prior to mixing.

2. Cement or flyash shall be stored in a dry place, in moisture-proof containers, free from lumps, with 100% passing the #16 sieve.

3. The moisture content of the fine and coarse aggregate shall be less than one-half of the SSD absorption unless otherwise required. The maximum size aggregate shall be 100% passing the 1" sieve. Care should be taken to avoid segregation of aggregate.

4. Water used in mixes shall be potable. The water temperature shall be between 70 and 76°F (21 to 25°C).

5. Packaged materials submitted for testing shall be in unopened packages. Broken packages may be cause for rejection. Packages shall be marked in accordance to ASTM C 928, Section 10. Entire packages shall be blended prior to sampling.

6. Prepacked materials shall be tested at the maximum aggregate extension recommended by the material supplier.

G. MIXING PROCEDURE

1. General. Mix the concrete overlay or patching material as specified by the material supplier in an electric mixer, drum or open tub type, or by hand, in a batch of such size to yield 5 percent excess after molding test specimens. Hand mixing procedures

are not applicable to air-entrained mixes or for mixes with no measurable slump. Follow the material suppliers recommendations as to the order of addition to mixes and mixing times. Materials shall be mixed thoroughly in the time allotted.

2. Mixing Time
   a. Mixing time starts when the liquid or powder component is added to the mix that initiates the reaction to the eventual setting of the combined materials.
   b. Mixing times will vary with the material being tested. Some portland cement mixes may be mixed for 3 minutes followed by a rest period of 3 minutes, then continue mixing for 2 minutes (3-3-2). Some fast setting materials may require only 1 minute of mixing.
3. Tests
   a. If the working time of the material is long enough, tests such as slump, unit weight, and air percentage may be taken if desired. Return all uncontaminated material to the mixer and mix for a minimum of 30 seconds before proceeding to mold specimens.
4. Begin molding the specimens within one minute after completion of the mixing.

H. MOLDING OF SPECIMENS

1. Molding of Abrasion Test Specimens for California Test 550
   a. Place a layer of the batched material in each compartment of the mold approximately 1 inch deep. Tamp the batch in each compartment 25 times with a ½ inch × 1 inch × 6 inch rubber tamper in a spiral motion, making sure all edges are tamped. Tamping shall be completed in each compartment before going on to the next. When the tamping of the first layer in all compartments is completed, jiggle the mold to remove entrapped air along the sides. Fill the compartments with the remaining batch and tamp as specified for the first layer. Upon completion the batch material should extend slightly above the top of the molds. With a trowel force the batch downward into the mold. When compaction is completed, strike off the top surface and finish to a smooth surface with a steel straightedge.
2. Molding of Flexure Test Specimens
   a. Place the batched material in the mold in two approximately equal layers. Compact each layer with a wooden tamper approximately ¾ inch × 3 inch × 18 inch long, 40 strokes for each layer or until a homogeneous specimen is obtained. Jiggle the mold between each layer to remove entrapped air. After the top layer has been compacted, strike off the material flush with the top of the mold, and finish to a smooth surface with a steel trowel.
3. Molding of Bonding Test Specimens
   a. Follow the material suppliers instructions for applying a bonding coat, if recommended, to the bond surface of the PCC sample blocks in the mold. PCC bonding test blocks shall be fabricated in accordance with Part IV, "Method for Fabricating PCC Blocks For Use In The Bond Test."
   b. Place the batched material in the mold in two equal layers. Compact each layer with a wooden tamper approximately ¾ inch × 3 inch × 18 inch long, 20 strokes for each layer or until a homogeneous specimen is obtained. Spade the PCC bond block bonding surface with a spatula to effect maximum contact of the batched material with the PCC. Jiggle the mold between each layer to remove entrapped air. Compact and strike off the material to the top of the mold, and finish to a smooth surface with a steel trowel.
4. Molding of Lineal Dimension Change Specimens
   a. Follow the instructions for molding of flexural test specimens making sure that the material is well worked into the corners and around the gage studs.
   b. Immediately after fabricating the specimen, loosen the gage studs at each end of the mold in order to prevent any restraint of the gage studs during initial shrinkage of the specimen.
5. Vibration of Molded Specimens
   a. If the mixed batched material has a slump of 3 in. or less, an external vibrator may be used in lieu of rodding and tamping.
   b. Maintain a standard duration of vibration for the particular kzind of material, vibrator, and specimen mold involved. The duration of the vibration will also depend upon the workability of the material and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the material becomes relatively smooth. Vibrate only long enough to achieve proper consolidation of the material. Over vibration may cause segregation. Fill the molds and vibrate in two approximately equal layers. Add the final layer, so as to avoid overfilling by more than a ¼ inch. After vibration, finish to a smooth surface with a steel straightedge.
   c. When external vibration is used, ensure that the

mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

I. CURING

1. In general, follow the material suppliers curing recommendations.

2. Curing methods are defined as specified in Part I, "Method of Test For Determination of Compressive Strength and Flow of Concrete Overlay and Patching Materials (Using 2" Cube Specimens)," Section H.

3. Specimens may be removed from the molds after the final set provided that the molds can be removed without damage to the specimen. Typically, molds may be removed after twice the final set time. All specimens should be removed from the molds within 48 hours.

4. Prior to, or shortly after removal from mold, identify each specimen using a waterproof marking pen.

J. TEST AGE

1. All test specimens shall be broken within the permissible tolerance prescribed as follows:

Test Age	*Tolerance*
1-2-3 hours	± 5 min.
6 hours	± 10 min.
24 hours	± ½ hour
3 days	± 1 hour
7 days	± 3 hours
28 days	± 12 hours

Intermediate test ages shall be broken within the tolerance of the earlier specified test age.

K. MIXING REPORT

1. The mixing report shall include the following:

a. Identification of overlay or patching material.
b. Tests to be run.
c. Number of specimens for each condition and age.
d. Identification and source of each material employed including lot numbers.
e. Type, maximum size, moisture condition, and gradation of the aggregate.
f. Mixing equipment used.
g. Order of addition of material into the mix.
h. Date, time, and air temperature at time of mixing.
i. Consistency of mix, odors, hazards, workability.
j. Method of fabricating molds and vibration information.
k. Curing procedure used.
l. Test operators.
m. Any other pertinent information, such as type, application of bond coat, test results or finishing characteristics.

REFERENCES

ASTM C 192
ASTM C 928
California Test 550

PART IV. METHOD OF TEST FOR FLEXURAL STRENGTH OF CONCRETE OVERLAY AND PATCHING MATERIALS

A. SCOPE

This method covers determination of the flexural strength of concrete overlay and patching materials by the use of a simple beam with third-point loading on 3 inch by 3 inch by 12 inch specimens.

B. APPARATUS

Apparatus shall be in accordance with ASTM C 78.

C. TEST SPECIMENS

The test specimens shall be fabricated and cured as specified in Part III, "Method for Fabricating Concrete Specimens of Overlay and Patching Materials." The sides of the specimen shall be at right angles with the top and bottom. All surfaces in contact with load-applying and support blocks shall be smooth and free of scars, indentations, holes, or inscribed identifications.

D. PROCEDURE

The procedure shall be in accordance with ASTM C 78, Section 5. Loading rate above 50% of the ultimate load shall be 1500 lbs per minute.

E. CALCULATIONS

Calculations shall be in accordance with ASTM C 78, Section 7.

F. REPORT

The report shall include the following:

1. Identification number.
2. Curing history.
3. Age of test specimen.
4. Maximum applied load in pounds.
5. Modulus of rupture calculated to the nearest 5 psi.
6. Test operators.
7. Defects in specimen or anything unusual.

REFERENCES

California Test 522
ASTM C 78

PART V. METHOD OF TEST TO DETERMINE THE BONDING STRENGTH OF CONCRETE OVERLAY AND PATCHING MATERIALS TO PCC

A. SCOPE

This method covers the determination of the bonding strength of concrete overlay and patching materials by a simple beam with centerpoint loading.

B. APPARATUS

1. Testing Machine
The testing machine shall conform to ASTM C 78.
2. Apparatus for bonding test.
   A. Base Plate
   The Base plate for this test shall be similar to the one specified in ASTM C 78 with a support length (L) of nine inches.
   B. A diagram of the apparatus and load-applying bar is shown in Figures A1 and A2. The load-applying bar shall provide a uniform point load along the length of the bond interface.

C. TEST SPECIMENS

The test specimens shall be fabricated and cured as specified in Part III, "Method for Fabricating Concrete Specimens of Overlay and Patching Materials." The sides of the specimen shall be at right angles with the top and bottom. All surfaces in contact with the load-applying bar and support block shall be smooth and free of scars, indentations, holes or inscribed identifications.

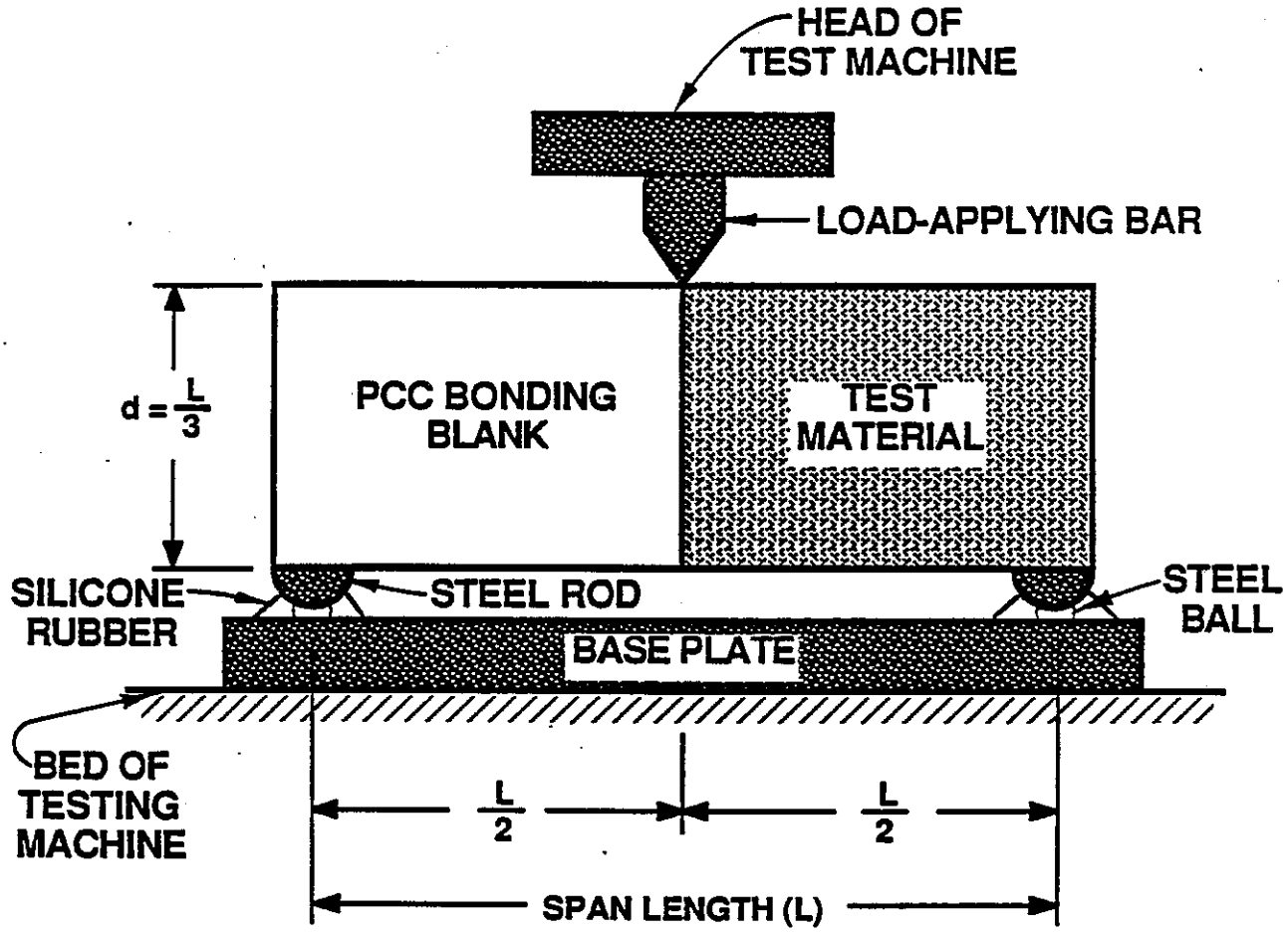
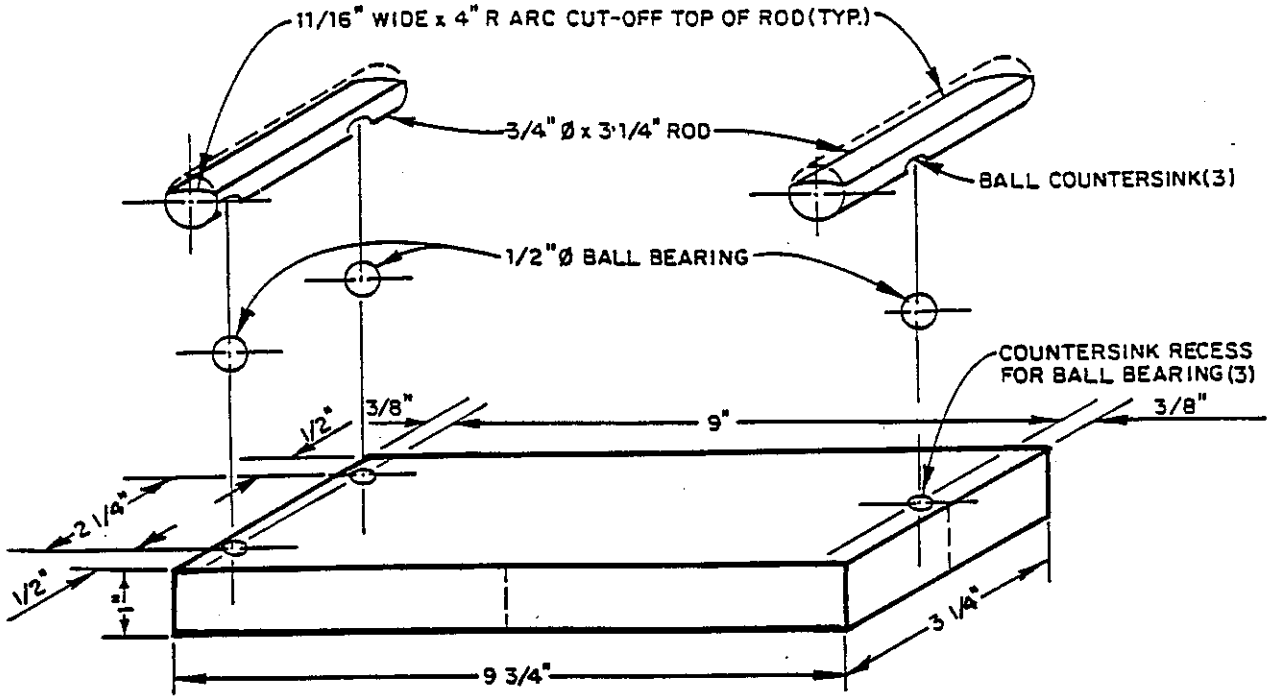
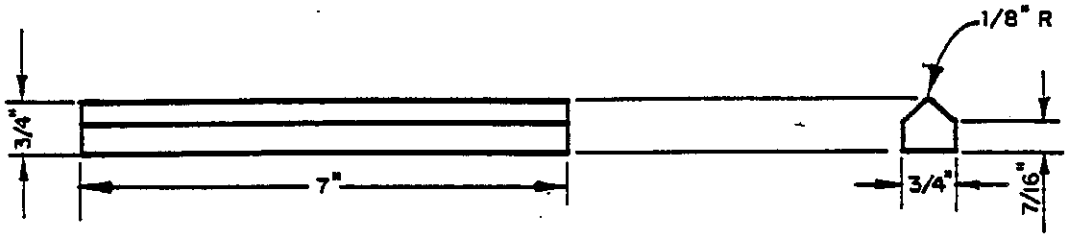


Figure A1, APPARATUS FOR BONDING STRENGTH TEST IN CENTER POINT LOADING



BASE PLATE



BAR FOR "BOND" TEST

NOTE: 1. BALL BEARINGS SILVER SOLDERED TO COUNTER-SINK IN 3/4"Ø x 3 1/4" ROD.
2. RODS CEMENTED TO BASE WITH SILICON RUBBER.

Figure A2

PLAN OF APPARATUS FOR BOND TEST OF CONCRETE OVERLAY AND PATCHING MATERIALS

D. PROCEDURE

Turn the test specimen on its side with respect to its position as molded so the top as molded is facing the operator. Center the bond face line on the support block. Center the loading system in relationship to the applied force. Lower the spherical head of the testing machine until there is enough clearance between the spherical head and the test specimen to insert the load-applying bar without tipping over. The load-applying bar shall be placed directly on the bond face line of the specimen.

Apply the load continuously at a rate of 1500 lb per minute until the specimen breaks. The specimen will break at the bond line, in the PCC or in the material being tested.

E. CALCULATIONS

Calculate the modulus of rupture in bond by dividing the maximum applied load by 2. Report as PSI.

F. REPORT

Since the failure can be in bond, PCC, or cohesive failure of the test material, it is important to note where the break occurred. If it broke in bond, so note. If it fractured in PCC or cohesive failure of the material, note approximate percentage of material broken.

The report shall include the following:

1. Identification number and name.
2. Curing history.
3. Age of test specimens.
4. Maximum applied load in pounds.
5. Modulus of rupture, to the nearest 5 psi.
6. Location of break and percentage.
7. Date tested and test operator.
8. Defects in specimen, or anything unusual.
9. Dry or SSD bond test.

REFERENCES

ASTM C 78

California Test 522

PART VI. METHOD FOR FABRICATING PCC BLOCKS FOR USE IN THE BOND TEST

A. SCOPE

This method covers procedures for making and curing PCC blocks for use in Part V, "Method of Test to Determine The Bonding Strength of Concrete Overlay and Patching Materials to PCC".

B. APPARATUS

1. The concrete mixer, scales, tamping rods, miscellaneous equipment and molds shall conform to ASTM C 192, Section 3 "Apparatus". The internal dimensions of the molds shall be 3 inches by 3 inches by 12 inches.

C. SPECIMENS

1. Portland cement concrete block specimens shall be made from aggregate passing the 1-inch mesh screen. Grading limits shall conform to Section 90-3.04, "Combined Aggregate Gradings," of the Standard Specifications. The concrete mix shall be a nominal 7-sack mix and achieve a minimum compressive strength of 4500 psi in 28 days. Concrete specimens used for freeze-thaw bond tests shall have an air content of 5 to 7 percent as determined by California Test 504 "Method of Test for Determining Air Content of Freshly Mixed Concrete by the Pressure Method". Admixtures shall conform to Sections 90-4.01, "General," and 90-4.03, "Admixture Approval," of the Standard Specifications.

D. PREPARATION OF MATERIALS

As specified in ASTM C 192, Section 5.

E. PROCEDURE

As specified in ASTM C 192, Section 6.

F. CURING

1. As specified in ASTM C 192, Section 7.1 and 7.2.
2. Specimens shall be placed in a moist cabinet or moist room where the temperature is approximately 75°F and relative humidity not less than 95% (ASTM C-511) for a period of at least 28 days.
3. After 28 days in the moist room, remove the specimens and place in dry storage. Samples should preferably be aged 6 months prior to use.

G. DIAMOND BLADE CUTTING

1. The 3 inches × 3 inches × 12 inches PCC blocks are cut approximately in half with a concrete saw with a water cooled diamond blade. The saw cut shall be at right angles to the length of the block.
2. Care shall be taken to avoid contamination of the cut face, especially with oil. After cutting, the PCC blocks are washed with clean water to remove all loose particles.

H. Saturated Surface Dry Bond Blocks

1. PCC blocks for use as Saturated Surface Dry (SSD) PCC shall be placed in a rust-proof container and end covered with a minimum of 1 inch of water for a minimum of 48 hours prior to test.
2. Remove PCC blocks from the water, rinse with clean water and dry with a clean paper towel.
3. Apply ¾ inch wide masking tape around the perimeter of the cut face. The tape application shall

be even with the cut face and not protrude more than 1/32 inch beyond the cut face.

4. Place the taped block into a 3"×3"×12" mold coated with a suitable mold release, the cut face shall be not less than 5 inches from the end of the mold. Secure the block in the mold.

5. Cover the SSD test samples with a damp towel until ready to place the material to be tested. This is done to retain the SSD condition of the block.

I. DRY PCC BLOCKS

1. PCC blocks used as dry PCC blanks shall be placed in an oven at 230±9°F (110±5°C) for at least 48 hours prior to testing.

2. Blocks shall be cooled to room temperature before using.

3. Apply a ¾" masking tape around the perimeter of the cut face. The tape application shall be even with the cut face and not protrude more than 1/32 inch beyond the cut face.

4. Place the taped block into a mold coated with a suitable mold release, the cut face shall not be less than 5 inches from the end of the mold. Secure the block in the mold.

REFERENCES
ASTM C192
ASTM C511
California Test 504

PART VII. METHOD OF TEST FOR CHORD MODULUS OF ELASTICITY OF CONCRETE OVERLAY AND PATCHING SPECIMENS (COMPRESSOMETER METHOD)

A. SCOPE

This procedure is used in determining the modulus of elasticity of concrete overlay and patching specimens using a compressometer. Alternate methods using a dial gage capable of reading to 1/10,000 inch or an electronic recorder for plotting a stress-strain curve are described.

B. APPARATUS

1. The apparatus shall consist of a testing machine and compressometer as described in California Test 522.

2. An adapter capable of holding a 3"×3" specimen in the compressometer.

C. TEST RECORD FORM

Record the concrete test data and the deformation readings from a dial compressometer on a suitable form. If a linear variable differential transformer (L.V.D.T.) and chart recorder are used, attach the plots.

D. TEST SPECIMENS

1. The test specimens may be cut from 3"×3"×12" concrete broken in flexure. The minimum length of the specimen is 6-inches, cut flush on a concrete saw. Both ends of the specimen shall have a square, plane surface. If not, cap the ends with capping compound. Uncapped specimens shall use a cardboard shim not less than .030 inch thickness to protect the bearing surfaces of the testing machine.

2. Test the specimens in a dry or room cure condition unless otherwise specified.

E. TEST PROCEDURE

1. The test procedure is the same as specified in California Test 522, Section E, except that the rate of loading shall be at the rate of 20,000 pound per minute.

F. CALCULATIONS

Same as specified in California Test 522, Section F.

G. TEST REPORT

The test report shall contain the following:

1. Specimen identification.
2. Cure history.
3. Condition of sample at time of testing.
4. Age of test specimen.
5. Test date and operator.
6. Calculation data.

H. PRECAUTIONS

Same as specified in California Test 522, Section G.

REFERENCES
California Test 522

PART VIII. METHOD OF TEST FOR SPECIFIC GRAVITY AND ABSORPTION OF CONCRETE OVERLAY AND PATCHING MATERIALS

SCOPE

This test method, which is a modification of ASTM C 127 covers the determination of bulk specific gravity and absorption of cured concrete overlay and patching materials.

A. APPARATUS

1. A balance or scale having a minimum capacity of 5000 grams, sensitive to ± 1 gram.

2. Suitable apparatus for holding the sample from the scale so that the weight of the sample in water can be obtained. Apparatus shall include a container of sufficient size to allow complete immersion of

sample while weighing.

3. A corrosion resistant vessel deep enough to permit immersing of samples during the soaking period.

B. PREPARATION OF SAMPLES

1. Each sample shall be a cured specimen free of surface cracks and have at least 800 grams dry weight. All loose surface material shall be removed.

C. TEST PROCEDURE

1. Immerse specimen in water, with a minimum of one inch of water covering the specimen and allow to soak for a minimum of 48 hours. Water temperature shall be 68 ± 9°F (20 ± 5°C).

2. Remove samples from the water, rinse clean, and place in apparatus suspended from scale or balance. Immerse the sample completely, correcting for tare weight, and weigh to nearest gram. Record weight as "weight of sample in water" (C).

3. Remove sample from the water and dry surface with a large aborbent towel to remove all visible water. Avoid loss of absorbed water by drying the sample to a saturated surface dry condition as rapidly as possible and then weigh immediately. Weigh the sample to the nearest gram. Record weight as "weight of saturated surface dry sample in air" (B).

4. Put sample in an oven and dry to constant weight at 230° ± 9°F (110 ± 5°C).

5. Cool sample to room temperature and weigh to nearest gram. Record the weight as "oven-dry weight" (A).

D. CALCULATIONS

1. Description of Factors
   - A = Weight in grams of sample in oven-dry condition.
   - B = Weight in grams of sample in saturated surface-dry condition.
   - C = Weight in grams or saturated sample immersed in water.
2. Bulk Specific Gravity equals

$$\frac{A}{B-C}$$

3. Percent Absorption equals

$$\frac{B-A}{A} \times 100$$

E. REPORTING OF RESULTS

Report specific gravity to the nearest hundredth and percent absorptions to the nearest tenth.

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California Test 552
March 1991

METHOD OF TEST FOR RELATIVE COMPACTION OF POLYMER CONCRETE UTILIZING NUCLEAR GAGES

A. SCOPE

This test method describes a quick and simplified procedure to determine the relative compaction of a polymer concrete overlay. It describes a procedure to obtain "standard density" and "in-place density" of compacted polymer concrete.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever chooses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Those using this standard do so at their own risk.

B. APPARATUS

1. Nuclear gage and standardizing block - see California Test 231.
2. A rigid frame, fabricated from angle iron or similar material, that forms a square test area, approximately 18 in. x 18 in. - see Figure 1. The height of the rigid frame shall be the nominal thickness of the polymer concrete overlay.
3. A wooden strike-off block, approximately 2 in. x 4 in. x 24 in.
4. Trowels
5. Shovels
6. Plastic containers (one to five gallons)
7. A rubber-headed mallet, weighing 1.25 ± 0.50 lb.

C. MATERIALS

1. Square polyethylene sheets, approximately 18 in. x 18 in. with thicknesses from 0.003 to 0.010 in.
2. Clean rags
3. Cleaning solvent.

D. STANDARDIZATION OF THE NUCLEAR GAGE

Standardize the nuclear gage as described in California Test 231.

E. STANDARD DENSITY TEST

1. The depth of this test is the nominal thickness of the polymer concrete overlay.

2. Place the rigid frame on the surface to be overlaid. Stabilize the rigid frame by placing heavy weights on the side extensions. Place a representative sample of freshly-mixed polymer concrete in the center of the rigid frame to adequately fill the 18 in. x 18 in. test area. Use dry, clean equipment (plastic containers and metal shovels) to transport the polymer concrete from the mixer to the rigid frame.

3. Use the wooden block to strike off the fresh polymer concrete. Place the block on top of the test area, with its 4-inch width touching the polymer concrete surface and its ends extending beyond the rigid frame. Use the mallet to strike the top of the block at various locations. Move the block, and re-strike as needed, to achieve uniform consolidation throughout the test area. The rigid frame must remain in full contact with the surface to be overlaid during the consolidation process. After consolidation, flushed resin should be evenly distributed throughout the surface of the polymer concrete.

4. Carefully remove the wooden block from the test area and place a sheet of polyethylene on top of the polymer concrete. Gently center the nuclear gage on top of the plastic sheet. Take a one-minute reading with the nuclear gage in the AC Backscatter mode. Carefully turn the nuclear gage 180 degrees and obtain a second one-minute reading. Average the two readings. Calculate the count ratio by dividing the count value by the average of the two readings. Use the calibration chart for the nuclear gage to determine the in-place density - see California

Test 231. This obtained value represents the standard compacted density for a day's use. If there is a significant change in the resin content, the depth of the overlay, the aggregate source or gradation, a new standard density must be determined.

5. For a valid test, sampling the polymer concrete, filling the rigid frame with material, compacting the polymer concrete, and obtaining nuclear gage readings must be completed within seven minutes.

6. Immediately after all nuclear gage readings are recorded, quickly clean the rigid frame and all equipment with the cleaning solvent before the polymer concrete begins to set. Properly dispose of all polymer concrete materials used in the compaction test.

F. IN-PLACE DENSITY TEST

1. Immediately after the polymer concrete has been placed and finished, and before any surface sanding or texturing, a relative compaction test must be taken. Place a sheet of polyethylene on the polymer concrete surface and gently place the nuclear gage on the polyethylene sheet. Take a one-minute reading with the nuclear gage in the AC Backscatter mode. Calculate the in-place density and the relative compaction of the material at the site. The formula to calculate percent relative compaction is:

$$\frac{\text{In-Place Density}}{\text{Standard Density}} \times 100 = \text{Percent Relative Compaction}$$

2. The relative compaction shall be rounded off to the nearest percent.*

G. REPORTING OF RESULTS

1. Record the operator's name, the CHC the nuclear gage, date of test and time of test.

2. Sketch the location of each test area (record P.M. or Station and distance left or right of centerline)

3. Record relative compaction results for each area (Do <u>not</u> average relative compaction values from or more test areas).

H. PRECAUTIONS

When handing polymer concrete materials, suitable protective clothing and eye protection Respiratory equipment may be required.

Reference: California Test 231

SPECIAL NOTE*

If any relative compaction value is less than that recommended specifications, the Resident Engineer should be notified [illegible] Most polymer concrete failures can be traced to insufficient [illegible] effort at the time of placement. The major factors for [illegible] compaction are presented below:

- **Too little resin in polymer concrete mixture**
- **Insufficient or incomplete mixing (dry spots in mix)**
- **Polymerization of material prior to compaction efforts**
- **The finishing machine moved too quickly to achieve adequate compaction**
- **Malfunctioning vibrators on finishing machine**
- **Too little compaction effort attempted**

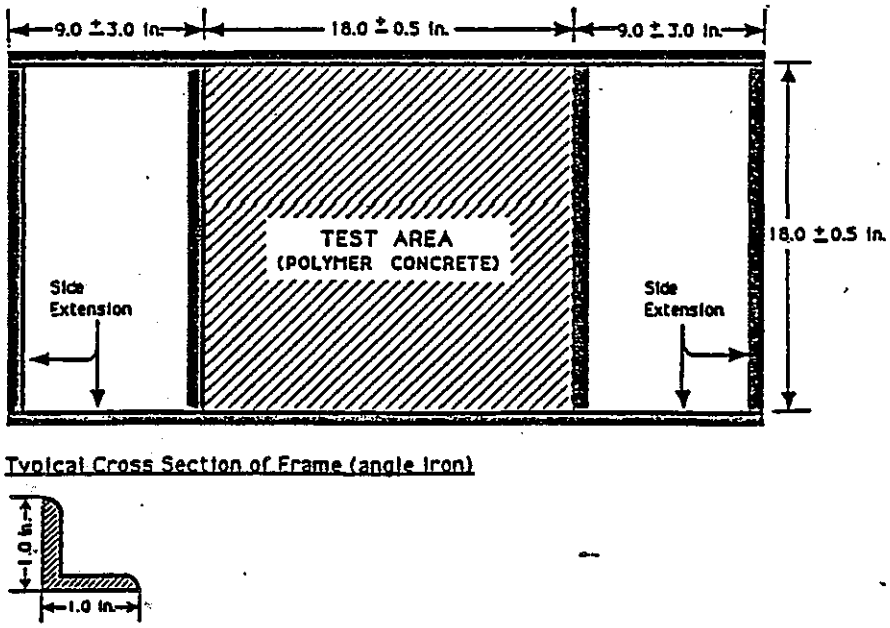

Figure 1 - Plan View of Rigid Frame (Polymer Concrete Compaction Testing)