

*Abridgment*

# Development of Performance Standards and Specifications for Polymer Concrete

Hans Peschke, Silikal North America, Inc., New Rochelle, New York  
Arthur M. Dinitz, Transpo-Materials, Inc., New Rochelle, New York

Because previous experiments using cement and latex-modified mortars did not produce the desired results in permanently rehabilitating highways, the German Democratic Republic's (GDR) Department of Transport in conjunction with the Research Agency for Highway Systems and the GDR Federal Highway Administration asked the chemical industry in 1960 to develop a polymer concrete that used reactive resins as the sole binder.

## REQUIRED CHARACTERISTICS OF POLYMER CONCRETE MATERIALS

This mortar had to meet several demands; it had to have

1. An application of layer thicknesses that could feather out to zero,
2. Good bond to existing concrete,
3. Short traffic down times,
4. Sufficient wear resistance,
5. Same evenness as concrete,
6. Sufficient skid resistance,
7. Good weather resistance,
8. Concrete-like color, and
9. Simple and easy mixing and good workability.

Although the items presented in this report are valid for all reactive resins—unsaturated polyesters (UP), epoxies (EP), polyurethanes (PU), and methyl methacrylate-acrylics (MMA)—we would like to go deeper into the MMA-bound systems. As it turned out, it was these systems that came closest to fulfilling the above demands. This became apparent when the first research contract was carried out in 1961 on the Frankfurt-Hannover Expressway near Kassel, as documented in a report by the former director of the Autobahn Administration Office in Frankfurt.

## ACRYLIC POLYMER CONCRETE MORTAR

A premixed powder containing fine sand and fine filler, polymers, initiators, pigments, and so forth is mixed with a measured amount of liquid monomer until a soupy mortar mixture is obtained. Mixing may be done in a polyethylene bag, one of which is supplied with every powder bag, by mechanical means or by manually rolling the bag back and forth while holding the open end closed.

The preparation is virtually the same as for cement mortars, where the sand-cement mixture is mixed with a certain amount of water. This simple and easy way of mixing is known to everyone working in the construction industry. Therefore it can also be carried out for MMA mortars. At the same time, the addition of coarser sand, from 2 to 15 mm (0.039–0.585 in), is well known from concrete technology and does not present a problem either. The mortar prepared in this fashion permits both the application of layers only about 3 mm thick and the feathering out of these layers to zero around the perimeter.

The binder proportion of this type of mortar amounts to about 11 percent by weight. By adding coarse aggregate from 50 to 150 percent by weight (without increasing the liquid monomer proportion) overlays may be executed and potholes repaired. Thereby the binder proportion is reduced to 5–9 percent. The pot life may be varied from 10 to 40 min. Curing time is 1–2 h even at temperatures down to  $-10^{\circ}\text{C}$  ( $14^{\circ}\text{F}$ ). The compressive strength ranges from 73.4 to 107.6 MPa (10 650 to 15 600 lbf/in<sup>2</sup>); flexural strength is between 19.6 and 34.3 MPa (2840–4970 lbf/in<sup>2</sup>); and the abrasion resistance is better than that of concrete.

## APPLIED RESEARCH AND DEVELOPMENT

### Required Characteristics of Polymer Concrete Material

The following demands were published in 1968 by the Research Agency for Highway Systems in a preliminary manual.

The fresh mortar has to meet these requirements. Its consistency must be such that it may be easily spread, consolidated, and screeded under the prevailing working conditions without forming voids at the contact area or within the mortar. The pot life should be as short as possible but at the same time must be long enough to facilitate a careful application of the mortar.

The cured mortar has to meet the following requirements. It must be water resistant, and its surface must have at least the same skid resistance and about the same color as the surrounding concrete. Its minimum compressive strength after 24 h should be 38.6 MPa (5600 lbf/in<sup>2</sup>) and its minimum flexural strength 5.3 MPa (770 lbf/in<sup>2</sup>). Its maximum modulus of elasticity after seven days should be 19 292 MPa ( $2.8 \times 10^6$  lbf/in<sup>2</sup>) and maximum linear coefficient of thermal expansion  $35 \times 10^6$  (m/m)/ $^{\circ}\text{C}$ . Maximum shrinkage by volume should be 0.1 percent.

A very good bond is obtained by using primers that must possess a certain degree of water compatibility. The use of a primer has further advantages. When using low-viscosity primers the upper concrete zone can be well penetrated. In general, this is the weakest link in reactive resin mortar overlays. The consolidation of the upper concrete zone considerably reduces the chances for spalling by winter weather or by shear forces from braking or accelerating vehicles.

The primer also prevents the binder from penetrating into the concrete substrate and the mortar from leaking out at the interface of the reactive resin and the concrete. It also improves the bond formation between the concrete and a reactive resin mortar that is lean in binders.

### Properties of Acrylic Polymer Concrete

#### Skid Resistance

For maintaining continuously good skid resistance, the

use of aggregate with different abrasion characteristics showed the best results, particularly if these aggregates were mixed into the mortar. Subsequent broadcasting of angular aggregate onto the overlay resulted in only temporarily acceptable skid resistance, and it was soon polished off by the traffic, as was found by a research project that will be referred to later.

### Mechanical Properties

The demand for high early compressive and flexural strength can easily be met by MMA-bound mortars, generally after 1-2 h.

### Thermal Properties

In order to prevent shear forces and thereby delamination along the interface of the polymer concrete overlay E-modulus, the product of the E-modulus and the coefficient of thermal expansion of the overlay should be about the same as the same product for the concrete substrate. This is why the manual demands an upper limit for both the E-modulus and the coefficient of thermal expansion.

### Polymerization Shrinkage

Finally, the demands low-shrinkage reactive resin mortars have to fulfill should be mentioned. As it turned out, shrinkage proved to be the biggest problem when one is working with polyester and methyl methacrylate resins, because both cure by polymerization.

Therefore, when one is working with MMA concrete, it is extremely important to work with as low a binder proportion as possible. When thicker layers are applied, it is even necessary to reduce the shrinkage of the monomer further by adding certain low-shrinkage monomers to keep shrinkage to less than 0.05 percent.

### PRETREATMENT OF SUBSTRATE

Pretreatment methods mentioned are sandblasting, using jackhammers, torching in conjunction with a subsequent mechanical treatment, steam-jetting, and using surface grinders, scabblers, scarifiers, and other methods to remove chemicals.

### APPLIED RESEARCH AND DEVELOPMENT PROJECTS FOR OVERLAYS

In 1972 another research contract combining previous knowledge and experience gathered on polymer concrete overlays was carried out by order of the GDR Federal Department of Transport in conjunction with the GDR Federal Highway Administration, Cologne, the Otto-Graf Institute, the Technical University of Stuttgart, and the Hessian Highway Department.

### Scope of the Project

A total of seven test areas were completed: five using epoxy-resins, one using an epoxy-tar combination, and one using acrylic resin.

### Results

After only one winter season of studded-tire traffic it became apparent that the broadcast material was more or less worn off or was completely broken out, depending on the characteristics of the material and the degree to which it was imbedded in the mortar. This resulted in drastic reductions in skid resistance properties. The

same values for homogeneous mortars, however, hardly changed.

This situation did not change for four years. However, all homogeneous mortar areas where material was subsequently broadcast had to be reworked in order to raise the skid resistance back up to the minimum.

The test area that received an epoxy-tar overlay had to be removed completely after four years, because the skid-resistance properties had again dropped below the permissible level, in spite of repeated post treatment; the major portion of the overlay had been worn down to the concrete substrate. Two-thirds of one epoxy resin overlay had to be removed completely because large areas separated from the substrate. The low skid resistance of the other three epoxy resin overlays was again objected to, although no objections were raised with regard to the acrylic overlay.

The above results were reported by the Otto-Graf Institute on an investigation of concrete roadways overlaid with reactive resin materials. In addition, results concerning the test area overlaid with acrylic mortar may be found in a report by Peter Quis and Hans Peschke.

About every six months for the duration of the four-year field test the bond to the concrete was tested by the strip-test method. Tests were also performed to measure skid resistance as well as abrasion. All test results were compared with those obtained in the laboratory. The object was to find a method that could be used to correlate field performance characteristics with laboratory test results and thereby determine the suitability of a particular reactive resin mortar for a particular application. This has now been done by using as its basis all collected data and the experience gained in the field.

### POLYMER CONCRETE APPLICATION MANUAL

An instruction manual for the maintenance and rehabilitation of concrete roadways that gives a method for the repair of surface and edge damages by using reactive resin has been published. The most essential elements of this manual are the requirements for the basic tests and their execution, which will enable one to determine the suitability of a reactive resin mortar material. The manual distinguishes between one mortar for overlays up to 15 mm (0.59 in) thick and another mortar for repairing potholes and patching.

The following tests must be carried out: (a) the cyclic freeze-thaw test in maximum application thickness for the first mortar and in minimum layer thickness of 20 mm (0.79 in) for the other, (b) pull-out tests 24 h after preparation and storage of the overlay at the minimum application temperature, (c) flexural strength test 24 h after preparation and storage at the minimum application temperature, (d) compressive strength test 24 h after preparation and storage at the minimum application temperature, (e) flexural strength test seven days after preparation and storage at standard conditions, (f) compressive strength test seven days after preparation and storage at standard conditions, and (g) infrared diagrams of the liquid components.

### RAILROAD APPLICATIONS

The Federal Railroad Association of West Germany, as well as that of France, has tested MMA mortars beyond their application as overlays for highways and roads to determine their suitability as shim material for bridge abutments. The Societe Nationale des Chemins de Fer (SNCF) of France even specifies MMA mortars.

## OTHER APPLICATIONS

Also successfully conducted were year-long trials to determine the suitability of MMA mortars for anchoring steel retaining bolts in concrete construction members for new high-speed [400 km/h (250 mph)] rail systems.

## CONCLUSIONS

1. Eighteen years of experience working with polymers in concrete have shown that early rehabilitation of concrete roadways with polymer concrete will prevent major deterioration problems.
2. Overlays on existing concrete roadways and bridge deck rehabilitation with polymer concrete result in a durable, highly skid-resistant road surface.

3. The use of polymer concrete is cost effective if all factors are taken into consideration.

4. From the information in the instruction manual of the GDR Federal Highway Administration, laboratory and field tests can now be performed to determine the true suitability of any proposed polymer concrete material to be used for rehabilitating concrete roads and bridge decks as well as for the existing substrate.

## ACKNOWLEDGMENT

We hereby acknowledge the cooperation and assistance of Walter Bloom and Franz Goetz.

*Publication of this paper sponsored by Committee on Adhesives, Bonding Agents, and Their Uses.*

### *Abridgment*

# Field Evaluation of the Gamma Scientific Model 910B Retroreflectometer

Gerald J. Malasheskie and Frank W. O'Block, Bureau of Materials, Testing, and Research, Pennsylvania Department of Transportation

To ensure that the Gamma Scientific model 910B retroreflectometer will perform satisfactorily in the field environment, the instrument was tested for performance, durability, and ease of operation under the following parameters:

1. Temperature range of 0-38°C (32-100°F),
2. Low and high relative humidity, and
3. Bright sunlight and cloudy lighting conditions.

In addition to the environmental parameters, the device was tested to determine whether it could be referenced to an optical tunnel. Since the device will be used to determine the compliance of reflective sheeting with Pennsylvania Department of Transportation (PennDOT) specifications, it is logical that measurements taken with it should produce the same results that the optical tunnel would provide.

If proved acceptable for use by PennDOT, the retroreflectometer will be used by both the bureau of materials and the sign shop to measure the initial specific luminance values of the sheeting material for compliance with the PennDOT specification for sheet-reflective materials. It will also be used in the field to determine when signs should be replaced. Evaluation for this use included measuring the specific luminance of signs taken from the field while still dirty and measuring them again after cleaning.

## OPERATION OF EQUIPMENT

The retroreflectometer consists of two units, the 910B retroreflectometer head (a pistol-shaped as-

sembly) and the 910 control unit (a rectangular assembly). A set of calibration standards supplied by the manufacturer was used throughout the testing sequence.

The retroreflectometer head contains all of the optics, the lamp source, and the detector. In use, the head is pressed against the surface of the sheeting to be measured. A small white plunger is then depressed flush with the front surface of the head. The depressing of this plunger turns on the lamp source and uncovers the detector, and a reading is then displayed. The head also contains the range switch.

The control unit contains the operating controls, the display, and the batteries. Before taking measurements, the unit was calibrated according to the color of the sheeting to be tested with the calibration standards supplied.

The 910B is designed for use in the field. Extended use throughout the evaluation has proved it to be rugged and built with high-quality components for long life and high reliability. However, like any instrument containing precision optics and sensitive electronics, it should be treated carefully. It should not be dropped or handled roughly. For field use the control unit may be carried on the hip by means of the shoulder strap supplied. The retroreflectometer head can then be pressured against the surface to be measured. If the surface to be measured is elevated, the head can be attached to a short pole for lifting it up against the surface.

A shielded hood has been attached to the digital display so that it may be read in full sunlight. The only precaution necessary is to keep the direct rays of the sun from striking the display. If they do, the display will be unreadable. When the control unit is on the