Poly. Conc File

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POLYMER CONCRETE DEVELOPMENT AND USE IN OREGON

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Oregon first became interested in polymer concrete in 1973 when the Federal Highway Administration offered to sponsor a polymer concrete overlay in this state. Because of the need to find a durable, quick setting, high early strength concrete for use in overlaying bridge decks in the Portland area, the offer was accepted.

The original work plan specified that laboratory tests would be conducted to determine the most suitable resins for overlay work. It must be pointed out that the Oregon State Highway Division was not set up to do polymer research, but only to test existing resin formulations that were readily available from chemical companies. After a literature search, two generic resins were chosen for study. They were methyl methacrylate and polyester styrene.

For those who are not acquainted with polymer concrete, it is a mixture in which a liquid resin is used for the total binder. The amount of resin is normally between 8 and 12 percent by weight of the aggregate depending on the gradation. Chemical additives are needed to cause the liquid resin to solidify. These chemicals are classified as an initiator, a promoter and an inhibitor. By varying the proportions of the chemical additives, the pot life and required cure time can be controlled for working temperature ranges.

Initial laboratory work consisted of preparing compression cylinders and examining the workability of polymer concrete mixes that were made without an inhibitor. The polymer concrete made with either methyl methacrylate or polyester styrene resins produced compressive strengths exceeding 5,000 psi in 4 hours when the handling time was limited to under ten minutes. When the handling time was extended to 25 minutes however, the compressive strength fell to under 500 psi. This problem was overcome with the introduction of an inhibitor which allowed the handling time to be increased to over 45 minutes without loss of strength.

Small polymer concrete overlays measuring 1½ in. thick were then placed on 18 in. sq portland cement concrete slabs for observation purposes. The polymer concrete overlays that were made with the methyl methacrylate resin had excessive evaporation of the resin. This produced a weak surface that was easily abraded. Because of this problem work with methyl methacrylate was abandoned and full attention was devoted to polyester systems. Recent reports have indicated bridge deck patching with methyl methacrylate polymer concrete has been successfully performed by Brookhaven National Laboratory.

Laboratory work with the polyester styrene systems was concentrated on studying physical properties such as compressive strength, splitting tensile strength, modulus of elasticity and modulus of rupture.

One of our major concerns was the ability to bond a polymer concrete overlay to an existing portland cement concrete deck. The use of a resin tack coat was found to be necessary to acquire a minimum 200 psi bond shear value consistently. Different methods of cleaning the substrate concrete were examined and it was first thought only sandblasting was necessary to remove surface laitance. Later experiences proved scarification or scabbling is necessary to remove undersirable surface mortar if superior bonding is to be achieved. Early laboratory tests indicated that moisture could be tolerated in the substrate but this was also proven to be wrong in the field.

In addition to the work with the resins, aggregate gradation was studied to produce the most economical polymer concrete mix. It was reasoned that a gradation with minimum voids would require less resin and thereby reduce the cost. Almost all early polymer concrete mixes made in the laboratory were produced using a narrow band aggregate gradation that contained about 19 percent voids.

When aggregate moisture content was found to reduce essential polymer concrete properties, a study was initiated to determine acceptable limits. Laboratory results showed the maximum allowable aggregate moisture content to be approximately 0.5 percent. This meant all aggregate used in polymer concrete work would require special drying.

When the polymer concrete study progressed to the point where large quantities of dry aggregate were required for field projects, it was found the optimum gradation determined in the laboratory was not economically available. In fact, no one was interested in producing it. Further laboratory study disclosed an acceptable aggregate gradation with tolerance limits which could be produced commercially. This gradation closely follows the 3/8 in. minus Fuller's maximum density curve. It is included at the end of this report.

Some of the physical properties of the polymer concrete formulation that Oregon has used in bridge deck patching and overlays are:

Ultimate Compressive Strength	4,000 psi in 5 hrs 8,000 psi in 24 hrs
Splitting Tensile Strength	1,200 psi in 1 day
Overlay Bond Strength	over 500 psi in 8 hrs
Modulus of Elasticity	2.5×10^6 psi in 1 day 2.9×10^6 psi in 7 days
Modulus of Rupture	2,150 psi in 1 day

Oregon's first polymer concrete bridge deck patch was placed on August 26, 1974 on the South Jefferson Interchange bridge. This structure is located on Interstate Highway 5 approximately 15 miles south of Salem. The nature of the problem was a concrete spall located in a wheel path near an expansion joint. Using a local maintenance crew with assistance from the laboratory the repair was made rapidly with good results. The size of the patch was 36 in. x 10 in. x 4 in. deep. The repair sequence was as follows:

1) Traffic was diverted to an adjacent lane.

2) The hole was prepared by removing unsound concrete with jackhammers and cleaning with high pressured air.

3) The polymer concrete was proportioned and mixed in a concrete mixer for approximately three minutes.

4) To ensure good bonding, a resin tack coat was applied by paint brush to the walls of the hole.

5) The polymer concrete was placed, compacted and finished within a five minute period.

Because the patch was small and handling time could be kept at a minimum, the additives were proportioned to allow a 15 minute pot life. This mix then required a cure time of only 60 minutes before traffic was allowed over the patch.

It is important to laboratory test each chemical ingredient for potency before going into the field by preparing a trial batch. The initiator planned for use in the first patch was found to be weak the day preceding the work. If that initiator had been used, the polymer concrete may never have set up and the patch would have been a failure.

The second deck patch worth noting occurred on the Sheep Creek bridge on U.S. Highway 20 in the Cascade Range. The problem with this deck was severe scaling in one area which measured approximately 24 ft by 15 ft. The exact cause of the problem was unknown, but it was guessed that additional water was applied during the finishing, causing a weak surface mortar.

Since the repair covered two traffic lanes, the regional maintenance engineer chose two patching products for comparison purposes. They were polymer concrete and Sinmast Epoxy Mortar #4. The preparation of this deck differed from the previous one since the unsound concrete was limited to the surface mortar. Using 16 lb chipping guns, the delaminated and scaled concrete was removed to a maximum depth of 1½ in. A vertical saw cut was also made around the periphery for additional edge section. This practice is recommended for all patching. The preparation was completed by sandblasting.

Using the same repair sequence as mentioned earlier, the polymer concrete was mixed, placed and finished. The method of compaction for this patch was a vibrating plate and the allowable handling time was extended to 30 minutes.

After a 120 minute cure the patch was opened to traffic.

The Sinmast and polymer concrete patches were last examined two years after installation. Both patches were well bonded to the deck, but some abrasion was found in each patch. The Sinmast patch had some minor cracking also.

One important difference between the systems was material cost. The Sinmast epoxy cost approximately six times more than the polyester styrene used in the polymer concrete.

The first attempt to place a polymer concrete overlay on a bridge deck was made in April 1975. The work was performed by a bridge maintenance crew with the assistance of laboratory personnel. The work consisted of overlaying one 30 ft x 24 ft wide span of the Santiam River bridge. The installation was not successful because bonding was not achieved. The lack of bonding was attributed to improper surface preparation and the presence of moisture in the deck. Only sandblasting was used to clean the deck and rain had occurred for several days before the laydown. Nightly temperatures in the low to mid 30's was also detrimental.

Small shrinkage cracks were observed in the polymer concrete within two days after completion. Additional cracking due to impact loading on the disbonded overlay became a noticeable problem after two weeks. The overlay was removed from the deck after being in service for 14 weeks. Pieces of the overlay that were examined during removal appeared to be very dense.

After additional laboratory study, a second attempt to overlay the same span was made on June 23, 1976. This time the overlay was successful.

As before, the work was done by a bridge maintenance crew with assistance by laboratory personnel. This time, however, the deck was in a dry condition and emphasis was placed on good surface preparation. Using a MacDonald pneumatic scabbler, the top ¼ in. of surface mortar was removed during the week preceding the overlay. The deck was also sandblasted just before the overlay was placed.

The time required to mix, place, and finish the polymer concrete overlay for each 12 ft by 30 ft lane was one hour. A cure time of 3½ hours was then allowed before traffic was allowed on the overlay.

When the overlay was examined one day after construction, it had small shrinkage cracks throughout and a slightly rough surface in one area. The overlay was well bonded to the deck and has remained that way for 2½ years. Some surface abrasion has occurred however, in the wheel tracks during the past year.

Because of the favorable results on the Santiam River bridge, the entire deck of the Crooked River bridge in Prineville received a 1½ in. polymer concrete overlay in May 1977. This structure is 180 ft long with a 26 ft roadway. Since traffic had to be maintained on the structure, the overlay could only be applied to one lane at a time.

On the day preceding the overlay, a brief meeting was held with the workers to acquaint them with polymer concrete. A slide presentation of the earlier laydown was shown along with diagrams of the work area, a list of work assignments and a tentative work schedule. This meeting greatly helped the coordination and efficiency of the entire overlay project.

The deck prepartion for this overlay consisted of removing the top ½ in of surface mortar with scabblers and sandblasting. The polymer concrete was mixed at the site in mortar type mixers and transported to the deck in a front end loader. As the polymer concrete was batched, a 15 mil resin tack coat was placed on the deck by paint rollers in an area which would be covered immediately by the overlay.

As the polymer concrete was deposited onto the deck, it was quickly spread by shovel and rake to a depth of 2± in. A modified 4 inch H beam riding on 2 x 4 screed rails, was used to strike the polymer concrete off at a desired depth of 1 3/4 in. When compacted, this produced a finished 1½ in. thick overlay.

During the first day, a vibratory sled compactor was used for consolidation. Because the overlay could not support foot traffic, the direction of the sled travel was transverse to the centerline. This method of compaction produced an extremely poor riding surface although the general quality of the polymer concrete appeared to be good. The lane was opened to traffic two hours after construction.

On the second day, a lawn roller was acquired to consolidate the adjacent traffic lane. The roller was approximately 3 ft wide and weighed 200 lbs when filled with water. As before, the direction of compaction was transverse to the centerline. The roller appeared to produce a smoother surface than the vibratory sled, but some shoving was still noticeable. When traffic was allowed on the overlay 2 hours after completion the ride quality was rated unacceptable.

Because of the rough ride the polymer concrete overlay was covered with a 1 in. leveling course of A.C. one month after construction. Except for the surface problem the overlay was considered successful because of the high early strength and good bonding characteristics. The in-place cost was estimated at $30/sq yd, which included deck preparation.

In an attempt to solve the finishing problem, a Bidwell SF-100 was used to consolidate two polymer concrete test panels in September 1977. The observed results were very favorable as the machine produced a smooth surface with satisfactory texture.

Using the technology developed in Oregon, the Idaho Department of Transportation is in the process of placing a polymer concrete overlay using a Bidwell finishing machine.

The following sample illustration of mix quantities and proportions can be used by those who wish to investigate polymer concrete further.

ILLUSTRATIVE PROBLEM

SAMPLE CALCULATIONS

Assume:

1.	Deck	30' x 120'	(10m x 40m)
2.	Resin Content	10% by wt. of aggregate	
3.	Aggregate Content	130 lbs/cf	(2,082.4 kg/m^3)
4.	1½" Polymer Concrete Overlay		(38.1mm)

Required Quantities:

Polymer Concrete	30' x 120' x 0.125' = 450 cf (12.74m^3)
Aggregate	450 cf x 130 lbs/cf = 58,500 lbs (26,535 kg)
Resin	58,500 x 0.10 = 5,850 (2,653 kg)

DESIGN MIX PER CUBIC FOOT (cf)

Assume ambient temperature 75°F (23.9°C)
See Table 1 for appropriate proportions

Aggregate 130 lbs (58.96 kg)
Resin (GR 11044) 130 lbs x 10% = 13.0 lbs (5.90 kg)
MEKP (Hi Point 180) 13.0 x 0.0125 = 0.1625 lbs (73.71 g)
12% Cobalt Octoate 13.0 x 0.0025 = 0.0325 lbs (14.75 g)
Dimethyl Aniline 13.0 x 0.0020 = 0.0260 lbs (11.80 g)
Tert-butyl Hydroquinone 13.0 x $\frac{100}{10^6}$ = 0.0013 lbs (0.59 g)

TABLE 1

RESIN FORMULATIONS FOR SEVERAL AMBIENT TEMPERATURE RANGES

	Temperature Range	Approximate Work Time Minutes	Initiator	Promoters		Inhibitor	Silane
			Hi-Point 180 * Percent	12% Cobalt Octoate * Percent	Dimethyl Aniline * Percent	Tert-butyl Hydroquinone PPM *	A-174 * Percent
Polymer Concrete	60-70	30	1.50	0.25	0.20	100	-
	70-80	30	1.25	0.25	0.20	100	-
	80-90	30	1.00	0.25	0.20	200	-
Tack Coat	60-70	15	1.25	0.25	0.20	100	2.0
	70-80	15	1.00	0.25	0.20	100	2.0
	80-90	15	0.80	0.25	0.20	200	2.0

* Component concentrations are percent of the resin by weight.