



The following excerpts were taken from the complete "Performance and Properties of Pavemend 30 and Pavemend 60 Rapid Repair Mortars" report completed by Dr. David A. Lange, Associate Professor of Civil Engineering at The University of Illinois at Urbana-Champaign, Urbana, IL in September 2003.

The report was conducted to evaluate the potential for using the Pavemend 30 and 60 minute materials for vertical construction applications. The excerpts taken from this report and contained within relate directly to repair applications.

The 60 minute material was not designed to be used as a repair material but rather as a ready-mix material. The Pavemend 5.0, 15.0, and 30.0 materials were designed to be used as rapid repair materials. Please refer to the McKinney & Co or Froehling and Robertson Inc. 3<sup>rd</sup> party engineering testing reports for material specifications.

For repair applications the 5.0 and 15.0 are deemed very rapid repair and the 30.0 as being a rapid repair material.

Additional testing is currently ongoing and will be made available as soon as it is completed. The projection is that it will be available within 90 days.

**\*\*Mix Protocol C required that the mix water (8.34 lb) be confirmed at 23 degrees C before the addition to the dry material. Pavemend 30 was mixed until the fluid compound reached a temperature of 30 degrees C, while the Pavemend 60 would be mixed until the compound reached 40 degrees C, regardless of mixing time in both cases.**

# **Performance and Properties of Pavemend 30 and Pavemend 60 Rapid Repair Mortars**

**Final Report prepared for**

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## **7. Ring-restrained Shrinkage Test**

### **7.1 Introduction**

The ring test was developed to observe the effects of restrained drying shrinkage. Porous materials created with water can fall subject to volumetric changes when the material is exposed to drying. The loss of moisture in the pores to the surrounding environment can cause shrinkage of the material matrix. When this shrinkage is restrained by boundary conditions (reinforcement, formwork, structural constraints, etc.), a residual stress is imposed on the material and can lead to cracking. The ring test allows for a porous material to shrink against a steel ring, measure the strain in the ring, and evaluate the cracking susceptibility of the material. The following section outlines the experimental work done with the ring test and the Pavemend 30 and 60.

### **7.2 Experimental**

The Pavemend material was mixed using Protocol C discussed in Section 3. , Materials and Methods, then cast into the ring formwork (two ring configurations – 0.5" and 1" thick steel ring) and covered with plastic wrap. After two hours of curing, the forms and plastic wrap were removed and the specimen was exposed to drying conditions of 23°C (+/- 2°C) and 50% relative humidity (+/- 4%). The test was carried out for 7 d of drying. The steel strains were measured by foil strain gages and data was collected at regular intervals for the duration of the test.

### **7.3 Results**

In, the strain data is shown as collected from the strain gages attached to the steel ring for each mixture. The low value of strain suggests minimal shrinkage occurred in the specimen that would apply a pressure to the steel ring.

### **7.4 Discussion**

As shown in Figure 20, the strains measured on the inner steel ring surface are quite low and confirms that the material undergoes very little shrinkage when exposed to drying during the first 7 d. The residual stresses calculated show low tensile, circumferential residual stress in the

specimen. This is due to the low shrinkage and high thermal expansion of the material. Both phenomena cause little pressure to the steel ring and therefore little strain is imposed back onto the specimen by the steel ring. Therefore, the residual stress in the specimen is well below the tensile strength of the material and no cracking occurred in the specimen during the testing period. In some cases the residual stress was compressive indicating that the steel ring may not be restraining shrinkage from the specimen, but being pulled by the expansion seen in the specimen.

## 7.5 Conclusions

- The ring test showed that Pavemend 30 and 60 may exhibit low drying shrinkage behavior. Due to the high thermal expansion of the material at early ages, the extent of volumetric changes attributed to drying shrinkage could not be confirmed.
- Low residual stresses were imposed on the specimen by the steel ring. This is credited to expansive behavior of the material that induced little pressure on the steel ring.

## 7.6 Figures

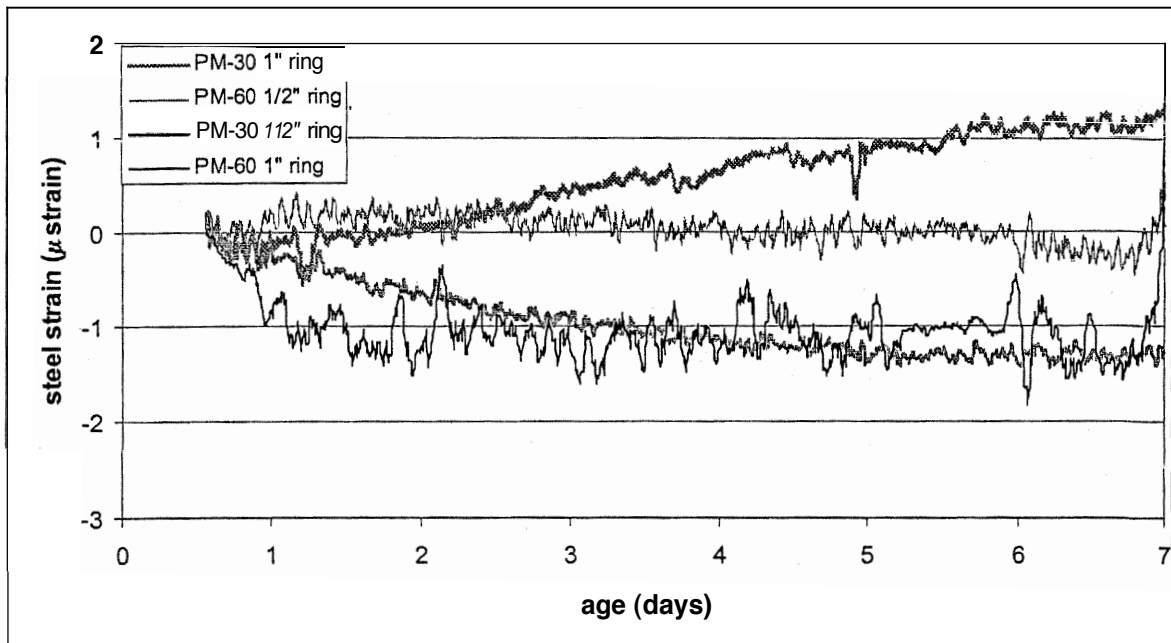


Figure 20. Measured Steel Ring Strains for Pavemend 30, 60

## **10. Interfacial Bond Testing**

### **10.1 Introduction**

The purpose of this experiment was to measure the bond strength development of Pavemend 30 (PM-30) and Pavemend 60 (PM-60) material mixed using protocol C. The bond strength was evaluated using procedures adapted from ASTM C882 -99 "Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete by Slant Shear."

### **10.2 Experiment**

ASTM C882-99 provides procedures by which bond strength is measured. The bond strength is determined by using the repair material to bond together two equal sections of a 3 by 6 in. portland cement mortar cylinder, each section of which has a diagonally bonding area at a 30° angle from vertical. The test is performed by determining the compressive load required to fail the composite cylinder. The bond strength is calculated as  $[\text{Max Load}]/[\text{Area of Slant Surface}]$ . In the test performed, one half of an ordinary portland cement (OPC) mortar cylinder was placed inside a polymer cylinder mold, and the remaining volume of the cylinder was filled with freshly mixed Pavemend.

To create the OPC mortar substrate, plain 3 by 6 in. mortar cylinders were cast. The mortar mix design (SSD) was 10 lb Type I portland cement, 30 lb river sand, and 4.8 lb water. After 2 d of curing, the cylinders to be used as substrates were sawn at a 30° angle from vertical into two equal sections. At 4 d, the surfaces of the sawn sections were sandblasted to achieve greater surface texture. All of the cylinders and sections were cured at 100% RH for at least 14 d and then removed from the curing room allowed to air dry in the laboratory for at least 2 d. The 21-d strength of the mortar was previously determined to be in excess of the 4500 psi required by ASTM C882-99 for the substrate material.

The composite cylinders for this experiment were fabricated by casting fresh Pavemend against one half of a OPC mortar cylinder which had been sawn and sandblasted.

Several (typically 3) replicate specimens were tested for each Pavemend material (PM-30 and

PM-60) at ages of 0.5 hr, 1 hr, 2 hr and 4 hr. The work was conducted in a lab environment held at  $23\pm 2^{\circ}\text{C}$ . The age of each test specimen is the elapsed time after the Pavemend half had set.

### **10.3 Results**

The test program proceeded without significant problems or unusual results. With very few exceptions, the upper portion of each cylinder failed as in compression testing before a partial or complete bond failure occurred. The only tests displaying a true bond failure were 0.5 hr PM-60 tests. The raw data from the tests and average bond strengths are shown in Table 1. A plot of the average bond strengths for the Pavemend 30 and 60 are illustrated in Figure 1.

### **70.4 Discussion**

The results show that PM 30 material develops strength more rapidly within the 24 hr after set over which the tests were conducted. This is consistent with early strength trends in shown Section 4. The specimens demonstrated excellent bonding characteristics, sufficiently strong to allow the material to fail before the bond. With the exception of the very early PM-60 tests, this trend indicates that Pavemend bonds well with OPC concrete with dry surfaces that have moderate surface roughness.

The absorption of free water into the pore structure at the cut cylinder surface may explain the relatively high cohesion at the interface of Pavemend with OPC mortar. Absorption at the interface acts as a dewatering mechanism for the local mass of Pavemend to reduce the water/binder ratio. The strength of the material at the interface, and consequently the overall bond strength, is likely significantly higher than that of the bulk of the material.

### **70.5 Conclusions**

Pavemend material bonds well with OPC product having adequate surface texture and dryness. The Pavemend bulk material may be expected to fail before a surface bond failure with OPC.

## 70.6 Tables

PM-30 material					
Time (hrs)	Average load/area	test 1 (lbs)	test 2 (lbs)	test 3 (lbs)	test 4 (lbs)
0.5	102.0	1440	1443.6		
1	1174.0	14752	19083	13645	18905
2	1252.8	16472	21337	15325	
4	1415.1	19933	18648	21436	
24	1493.5	23216	21001	19122	14772
PM-60 material					
Time (hrs)	Average load/area	test 1 (lbs)	test 2 (lbs)	test 3 (lbs)	test 4 (lbs)
0.5	268.1	4113	3164	4093	
1	572.6	7633	8285	8365	
2	691.4	9331	9215	10777	
4	852.3	11924	12557	11667	
24	1025.0	13961	14614	13921	15464

Table 10-1. Bond strength development of Pavemend 30,60 raw data.

## 107 Figures

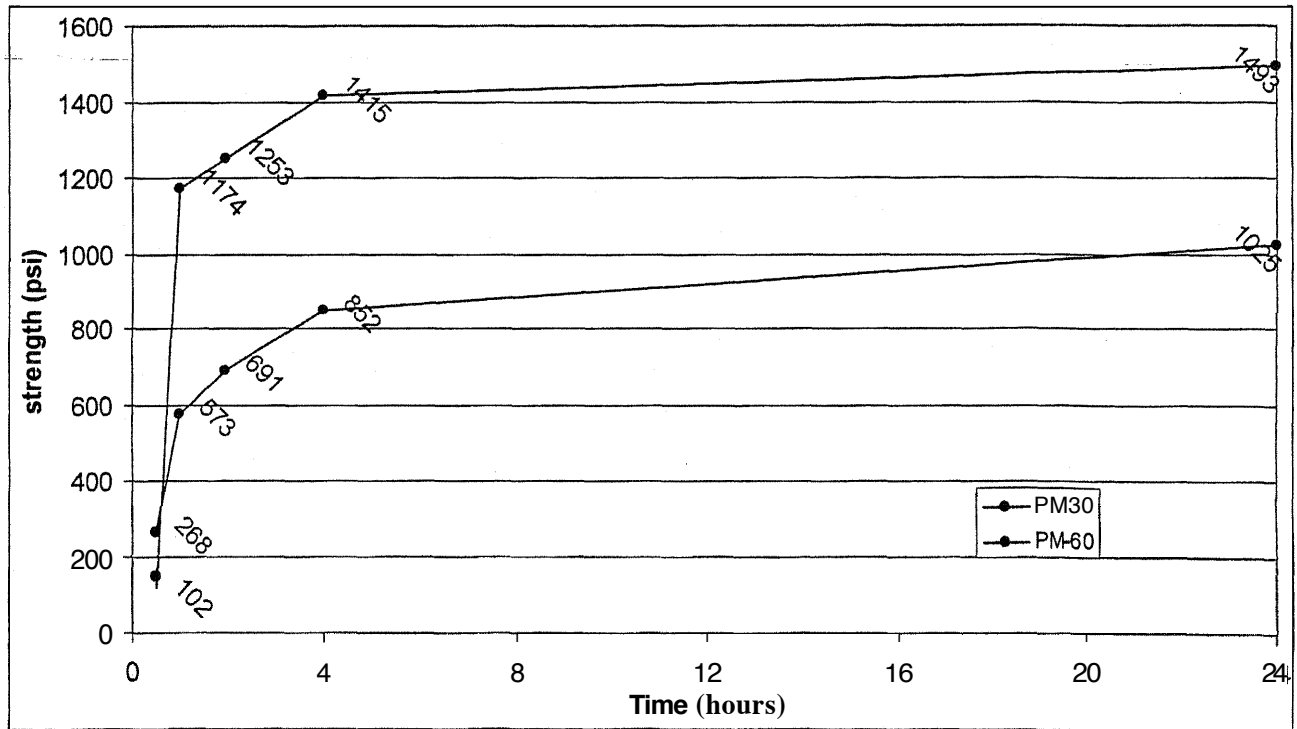


Figure 39. Bond strength development of Pavemend 30, 60 over 24 hr.