Characterization of Physical Properties of Roadware Clear Repair Product

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Introduction

Roadware MatchCrete Clear (MCC) is a two component aliphatic polyurethane for repairing cracks, spalls, and joints in concrete subject to UV exposure from sunlight. This material is clear in appearance when applied and cured. Colored sand and pigments may be added to create color stable repairs that match most any decorative or shade of concrete surface. MCC will not yellow with exposure to sunlight over time.

A repair material must have attractive workability and flow in order to successfully consolidate against the concrete substrate, so an important issue is ease of application. The ease of application in the case of *MCC* is largely a function of its low initial viscosity and rapid set time. The initial viscosity of *MCC* is similar to Concrete Mender (8 cps) and it gains rigidity within minutes.

Shrinkage of repair materials should be minimized so that high stresses do not form and lead to debonding of the interface with the concrete substrate. The potential for shrinkage stresses are commonly evaluated by free shrinkage tests, although in practice it is important to realize that creep relaxation is an important mechanism for reducing the level of stress in the repair.

Last, it is important to understand the stiffness of the repair material. Polymeric repair materials usually have a Modulus of Elasticity that is much lower than that of the concrete substrate. This generally has a positive influence on durability because it means that the repair is relatively flexible and resistant to brittle fracture and debonding. A low Modulus of Elasticity also implies that the repair will not highly restrain the substrate and thus create local regions of high stress.

Experiments and Results

Five experiments were conducted in this study. These experiments and results are discussed in the following sections.

A. Compression Strength

According to ASTM D695-08, prism specimens of 0.5” by 0.5” by 1” were obtained to test the compressive properties of *MCC*. These specimens were cut from a 0.5” by 1” by 11” prism made in a steel mold by pouring the *MCC* after mixing the two components for one minute in a glass beaker.

The compression stress-strain diagram of one of the five prisms tested is presented in *Chart 1*. There are three different regions in the observed behavior. First, the response is almost linear until the strain reaches about 30 % of the original length achieving a stress of 3 MPa. At 50% strain, the behavior changes somewhat toward “strain hardening.” Eventually, at about a 60 % strain, the behavior changes to an almost horizontal slope that means a yield point is being reached. In this yielding region, the material is being damaged and substantially cracked until complete failure of the sample.

The average compression strength is 2300 (15.9 MPa) related to a strain between 70 and 75 %. The compression yield point is roughly 2175 psi (15 MPa) stress and 60 % strain. Therefore the material is capable of very high elastic deformation.

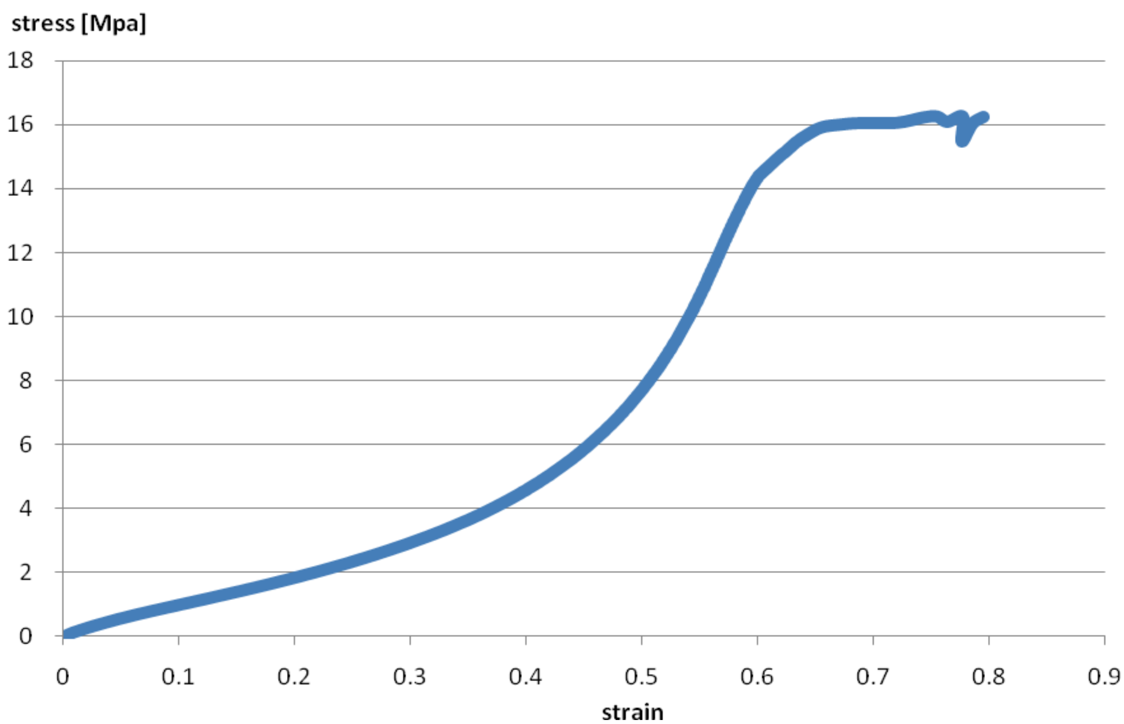

Chart 1 – Compressive stress-strain diagram of one of the samples

B. Modulus of Elasticity measured in flexure

ASTM D5984-08 provides procedures by which the modulus of elasticity of thermoplastic and thermosetting can be measured. Rectangular bars of 2 by 6 by 25 mm cut from a prism of 0.5” by 1” by 11” made in a steel mold by pouring the *MCC* after mixing the two components for one minute in a glass beaker were obtained to carry out the test.

The bar rests on two supports and is loaded by means of a loading nose midway between the supports. The test specimen of known geometry is placed under mechanical linear displacement using a controlled rate of loading. The modulus of elasticity is measured using three-point bending. This test method provides a simple means of characterizing the mechanical behavior of plastics materials using very small amounts of material.

The test is terminated if the maximum strain has reached 3 %, or the proportional limit, the yield force, the rupture force, or the maximum force of the analyzer has been reached, whichever occurs first. Due to the low thickness of the specimen and the low stiffness of the material, the 3 % strain is always the most restrictive condition. The average stress related to a 3 % strain is 100 psi (0.7 MPa), so the modulus of elasticity is 23 MPa.

C. Shrinkage

A free shrinkage test was conducted on a samples of *MCC* from about 90 minutes after mixing until 7 days of age. The samples were neat *MCC* with no added sand. The samples were 0.5" x 0.5" x 5" prisms with two metal contact points embedded at the ends. The sample length was monitored over time using a micrometer.

Assuming a coefficient of thermal expansion, $C_t = 1.0 \times 10^{-4}$ in/in/°F (a textbook value for similar urethane material), the initial length change within the first hours is explained by thermal effects as the temperature dropped from 130°F to 75°F. Subsequent shrinkage from 1 hour to 7 days represents inherent shrinkage that characterizes these kinds of polymers during their extended curing process.

Chart 2 illustrates the length change with time of different samples. The results demonstrated that *MMC* exhibits low shrinkage after curing. The observed shrinkage for five samples was 0.7%, 0.7%, 0.5% 0.0%, 0.0% for an average of 0.4%.

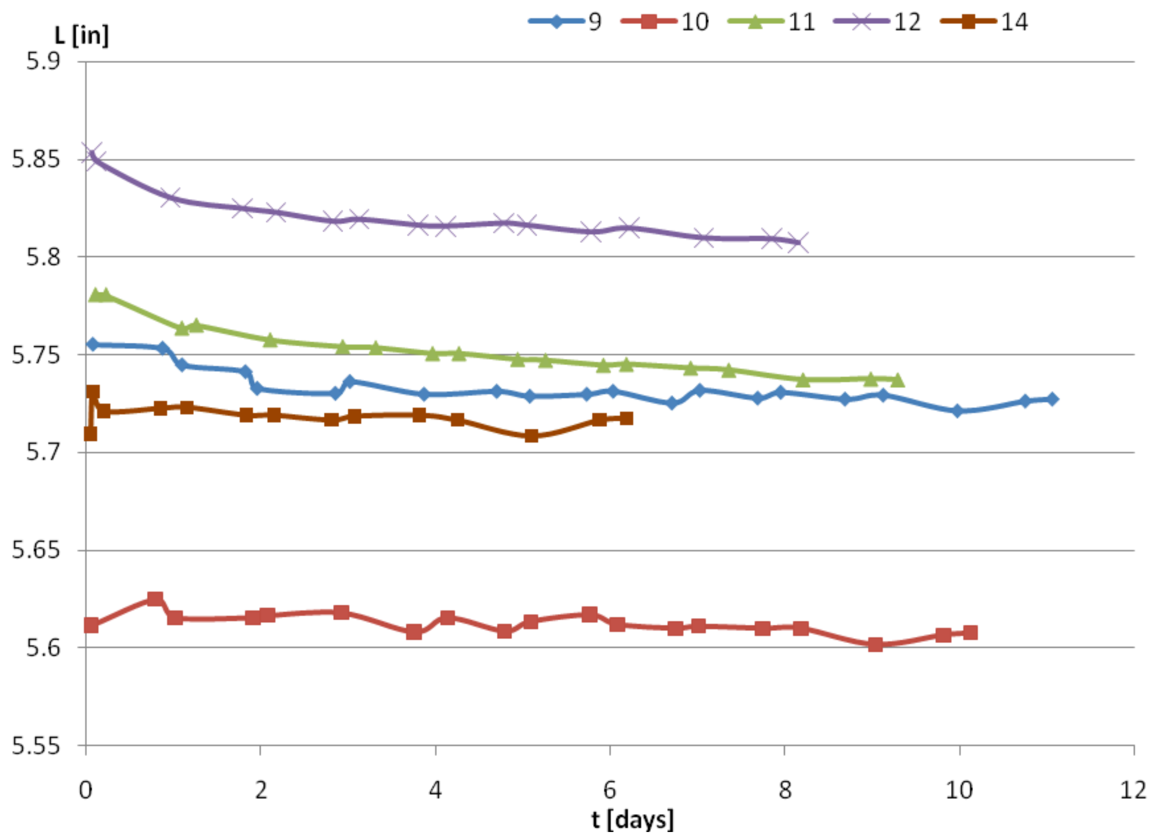

Chart 2 – Length of specimens with time due to shrinkage

D. Bond Strength

ASTM C882-05 provides procedures by which the bond strength of epoxy-resin systems are measured. The bond strength is determined by using the epoxy-resin system, or in this case, *MMC* to bond together two equal sections of a 3 by 6-in. portland cement mortar cylinder, each section of which has a diagonal bonding area at a 30° angle from vertical. After suitable curing of the bonding system, the test is performed by determining the compressive load required to fail the composite cylinder.

Plain 3 by 6 in. mortar cylinders were cast for use as substrates. The mortar mix design (SSD) is shown in *Table 1*.

Constituent	Weight (lb)	Weight (%)
Cement	10.60	22.27%
River Sand	31.90	67.01%
Water	5.10	10.72%

Table 1: Mortar mix design

After two days of curing, the cylinders to be used as substrates were sawn at a 30° angle from vertical into two equal sections. At 14 days, the surfaces of the sawn sections were sandblasted to achieve greater surface texture. Four extra cylinders were cast to be tested in compression to determine the strength of the mortar. All of the cylinders and sections were cured at 100% RH for 14 days and allowed to air dry for 14 additional days. The 28-day strength of the mortar determined as an average strength of the four whole cylinders was 6580 psi for the first samples and 7480 psi for the second ones, well in excess of the 4500 psi required by ASTM C882-99 for the substrate material.

The composite cylinders were fabricated by bonding two matched cylinder sections together. The procedure followed was generally in accordance with ASTM C882-05 Section 10.3.2 which is intended to be used for low viscosity bonding systems. In brief, the two cylinder halves were primed with neat *MCC*, positioned with a gap of approximately 0.02 in., wrapped with a self-adhesive aluminum foil except for a single opening, and then *MCC* was poured into the exposed joint opening until completely filled.

The three replicate samples had an average bond strength of 392 psi (2,71 MPa). It is reasonable to report the bond strength as a round number of 400 psi.

E. Tensile Strength and Elongation at Failure

Tensile tests were carried out in accordance with ASTM D638-08. Samples were fabricated by preparing a thin sheet of *MMC* and then using a bandsaw to cut dogbone-shaped specimens of acceptable dimensions. Setup dimensions are presented in Table 2 and test results are presented in Table 3. The tensile strength of the *MMC* was 450 psi (3.1 MPa), the extent of elongation at failure was 44%, and the tensile modulus of elasticity was 909 psi (6.27 MPa).

Width of Narrow Section	8.5-10.5 mm
Length of Narrow Section	51 mm
Thickness	2.5-3 mm
Width Overall	19 mm
Length Overall	135 mm

Table 2: Tensile test specimen dimensions

Sample	Tensile Strength (MPa)	Extent of Elongation (mm/mm)	Modulus of Elasticity (MPa)
1	3.166	0.485	6.300
2	3.210	0.477	6.059
3	3.108	0.423	6.344
4	3.434	0.468	5.816
5	2.682	0.357	7.058
6	2.973	0.415	6.062
Average	3.096	0.437	6.273

Table 3: Tensile test results

Summary

Roadware Matchcrete Clear is a low viscosity repair material with properties and performance that are well-suited for non-structural repair applications. The material provides excellent penetration of voids, ability to flow into fine cracks, rapid hardening, good adhesion and bond, and high deformability to provide a durable repair. The shrinkage of *MCC* is low and should not pose concern for debonding or delamination due to volume changes. The properties of Roadware Matchcrete Clear are summarized in Table 4.

Property	Measured Value
Tensile Strength	450 psi (3 MPa)
Compressive Strength	2300 psi (15.9 MPa)
Bond Strength	400 psi (2.7 MPa)
Elongation to yield in tension	44%
Elongation to yield in compression	60%
Modulus of Elasticity (flexure)	3300 psi (23 MPa)
Modulus of Elasticity (tension)	900 psi (6.27 MPa)

Table 4: Summary of Properties

In summary, Roadware Matchcrete Clear is a strong and flexible repair material suited for sealant applications. The material bonds well to concrete and will easily conform to slight deformations at repaired joints. The combination of good bond and low modulus predicts good service as a sealant or other non-structural repair material for concrete structures.