

# **GRAFFITI RESISTANCE OF WAX-BASED AND EPOXY-BASED COATINGS ON STEEL AND CONCRETE SUBSTRATES**

**By**

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## **ABSTRACT**

The graffiti resistance of two coatings developed by MicroCor Technologies, Inc. – MicroCor-300 and MicroCor-500 – was analyzed on steel and concrete substrates. The coatings were tested in accordance with ASTM D6578 Standard Practice for Determination of Graffiti Resistance and ASTM D7089 Standard Practice for Determination of the Effectiveness of Anti-Graffiti Coating for Use on Concrete, Masonry and Natural Stone Surfaces by Pressure Washing. In addition, the coatings were evaluated for time of set (ASTM D1640) and chemical resistance (ASTM D1308). Of the two coatings, MicroCor-300 demonstrated better overall graffiti resistant qualities on both steel and concrete surfaces but was not as durable as MicroCor-500. Therefore, MicroCor-300 should be reapplied after each cleaning cycle for its graffiti resistant qualities to remain effective.

## **ACKNOWLEDGEMENTS**

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## INTRODUCTION

Graffiti, “writing or drawings scribbled, scratched, or sprayed illicitly on a wall or other surface in a public place” (Oxford 2015), is an expensive issue that affects a majority of communities across the United States. Graffiti markings can be made with a variety of materials including but not limited to paint, markers, pens, and wax-based substances. Although graffiti is not typically associated with damaging structural integrity, property owners view the markings as aesthetically displeasing; therefore, laborers are sent to remove graffiti markings which has proven to be a time consuming and expensive task. In 2006, an annual cost of graffiti removal was estimated at \$12 billion nationwide (Weisel). To mitigate these costs, anti-graffiti coatings have been developed by various companies to either resist the application of graffiti or aid in its removal.

One company in particular, MicroCor Technologies, Inc., has developed two coatings with graffiti resistant qualities that can be applied to steel and concrete surfaces. This report describes the research and analysis of the graffiti resistance of the two coatings in accordance with ASTM D6578 chemical testing procedures and ASTM D7089 pressure washing methods. In addition, the coatings were evaluated for time of set (ASTM D1640) and chemical resistance (ASTM D1308).

## **EXPERIMENTAL WORK**

MicroCor Technologies, Inc. has developed two coatings, MicroCor-300 and MicroCor-500, which can be applied to steel and concrete surfaces to aid in the removal of graffiti, among other properties. The coatings were applied to steel and concrete surfaces to evaluate the graffiti resistance in accordance with ASTM D6578 (chemical testing) and ASTM D7089 (pressure washing). Coatings were also evaluated for time of set (ASTM D1640) and chemical resistance (ASTM D1308). Furthermore, the results were then compared to current KDOT Specifications shown in Appendix A.

### **Coating Application**

MicroCor-300 (MC-300) is a paraffin wax based coating which was applied to specimens via compressed air sprayer using 15-20 psi air flow to create an even film on the surface of the specimen. Three coats were applied with 10-minute intervals between coats.

MicroCor-500 (MC-500) is a two-part resin that was mixed as per manufacturer's instructions and applied to the specimens via paintbrush. Three coats were applied with an hour between coats.

Both coatings were allowed to cure on the specimens for seven days prior to the first test.

### **Time to Set (ASTM D1640)**

After coatings were applied to the specimens, set-to-touch time and dry-through time were evaluated in accordance with ASTM D1640. Set-to-touch time was analyzed by lightly touching the test film with a clean fingertip and observing if any of the coating was transferred. The film was considered "set-to-touch" when it was still in a tacky condition, but did not adhere to the fingertip.

Dry-through time was tested by pressing a thumb to the film, exerting the maximum pressure of the arm to the thumb upon the surface of the film, and turning the thumb 90°. The coating was considered “dry-through” when there was no loosening, detachment, wrinkling, or any other distortion of the film.

### **Chemical Resistance (ASTM D1308)**

The coated steel and concrete specimens used for ASTM D6578 chemical testing procedures were analyzed for chemical resistance using the open spot test procedure in accordance with ASTM D1308. A small amount of the selected reagents, paint thinner and gasoline, were placed on the coating for 15 minutes and then wiped off the specimens. The specimens were then observed for any alterations to the surface such as discoloration, blistering, swelling, or adhesion loss.

### **Graffiti Removal Using Chemical Testing (ASTM D6578)**

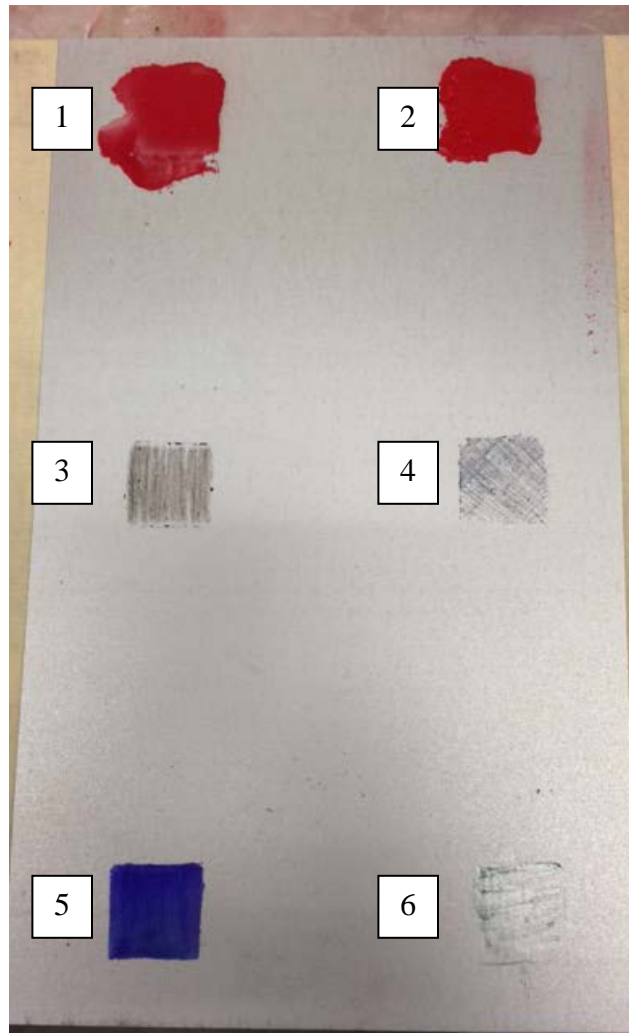
For chemical testing procedures, various materials typically used as graffiti markings were applied to all test specimens and allowed to dry for 24 hours. The markings were then removed with a series of cleaning agents starting with a dry rag and ending with aggressive cleaners. After the best attempts of graffiti removal, the markings were evaluated and given individual cleanability levels based on the cleaning agent required to completely remove the graffiti. The procedure was performed a total of ten cycles to assess recleanability.

Test specimens were made in accordance with ASTM D6578. A total of nine concrete blocks were cast with nominal dimensions of 6 in. × 12 in. × 3 in. and allowed to cure for 28 days prior to testing. An additional nine specimens were made using 6 in. × 12 in. steel plates.

For both concrete and steel, three specimens were coated with MC-500, three with MC-300, and three were left uncoated to act as control specimens.

A 6 in. × 12 in. template was constructed with a 0.5 in. perimeter and 1 in. × 1 in. square holes equally spaced for the application of designated graffiti markings as shown in Figure 1; (1) red solvent-based acrylic spray paint, (2) red solvent-based alkyd spray paint, (3) black wax crayon, (4) ballpoint ink pen, (5) blue solvent-based permanent ink marker, and (6) black water-based ink marker. The graffiti marking was classified as “repellant” if the marking material did not uniformly cover or adhere to the test area. After graffiti application, specimens were stored for 24 hours before removal was attempted.





**Figure 1:** Chemical Testing Graffiti Application

The graffiti removal process consisted of an attempt to remove each marking with a lint-free cotton cloth and series of cleaning agents. First, the dry cotton cloth was used alone. If the marking was not completely removed, a new cloth was saturated with the following cleaners in working order: a mild detergent (5% sodium phosphate solution), isopropyl alcohol (IPA), mineral spirits, xylene, and methyl ethyl ketone (MEK). The cleaners were used in order until the marking was removed or it was evident that no more of the marking was removable. Evaluation of the level of cleanability is shown in Table 1.

**Table 1:** Cleanability Ratings (from ASTM D6578)

<b>Cleanability Rating</b>	<b>Description</b>
Repellant	A mark could not be made on the surface with the marking material
10	Complete removal with a dry cloth
9	Complete removal with 5% sodium phosphate
8	Complete removal with isopropyl alcohol
7	Complete removal with mineral spirits
6	Complete removal with xylene
5	Complete removal with methyl ethyl ketone
4	Not cleanable-gloss loss
3	Not cleanable-slight shadow
2	Not cleanable-heavy shadow
1	Not cleanable-heavy shadow and gloss loss

The procedure was performed over a total of ten cycles to assess recleanability. According to ASTM D6578, “the recleanability is classified as the number of cycles performed until the marking is no longer cleanable”.

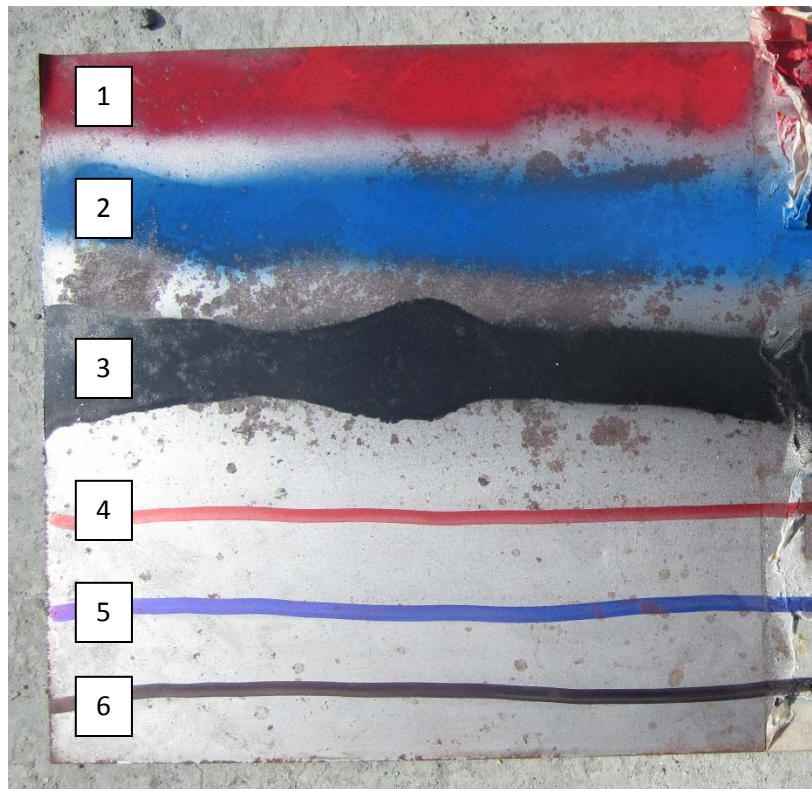
**Graffiti Removal Using Pressure Washer (ASTM D7089)**

For pressure washer testing, various colors of spray paint and permanent marker were applied to all specimens. After five days of drying, the graffiti was removed via commercial pressure washer and, if necessary, commercial graffiti cleaner. More aggressive cleaning methods specified in ASTM D7089 were not applicable for this project. The procedure was performed a total of ten cycles to assess recleanability.

Test specimens were made in accordance with ASTM D7089. A total of nine concrete blocks were cast with nominal dimensions of 12 in. × 12 in. × 8 in. and allowed to cure for 28 days prior to testing. Three specimens were coated with MC-500, three with MC-300, and three were left uncoated. An additional four specimens were made using 12 in. × 12 in. steel plates.

Two of the steel plates were cleaned of corrosion products prior to application of coatings while the other two were left as received. Of the four steel specimens, MC-300 was applied to one cleaned steel plate and one as-received steel plate. The other cleaned steel plate and as-received steel plate were left uncoated to act as control specimens.

The graffiti application for pressure washing specimens consisted of a series of six parallel lines as shown in Figure 2; (1) red, (2) blue, and (3) black acrylic spray paint and (4) red, (5) blue, and (6) black solvent based permanent markers. The graffiti was allowed to cure for five days before the graffiti removal process was attempted. A commercial pressure washer at 4 GPM and 1500 psi with a 15 degree nozzle was utilized to remove the graffiti. Evaluation of the level of cleanability is shown in Table 2.



**Figure 2:** Pressure Washer Test Graffiti Application

**Table 2:** Cleanability Ratings (from ASTM D7089)

<b>Cleanability Rating</b>	<b>Description</b>
Cleanability 1	Graffiti completely removed with high-pressure cold water wash
Cleanability 2	Graffiti completely removed with commercial based graffiti remover and high-pressure cold water wash
Cleanability 3	Graffiti completely removed with high-pressure hot water wash
Cleanability 4	Graffiti completely removed with a sodium bicarbonate pressure wash

Each cleaning cycle consisted of two graffiti removal attempts evaluating for Cleanability Levels 1 and 2. The first removal attempt was a cold pressure wash only. If the graffiti was completely removed, the specimen was labeled as Cleanability Level 1; otherwise, the percentage of the paint and marker removed was recorded. The second removal attempt required the application of a commercial graffiti remover. The product was sprayed on the surface of the specimen and allowed to sit for ten minutes as per manufacturer's instructions before another cold pressure wash attempt was made. If the graffiti was completely removed, the specimen was labeled as Cleanability Level 2; otherwise, the percentage of the paint and marker removed was again recorded. Further levels of cleanability as specified in ASTM D7089 were not investigated in this project due to failure to comply with KDOT specifications which require pressure washer test specimens to be Cleanability Level 1 (refer to Appendix A). The procedure was performed over a total of ten cycles to assess recleanability.

## **RESULTS**

### **Time to Set (ASTM D1640)**

MC-300 exhibited a set-to-touch time of 15 minutes and a dry-through time of 1.5 hours.

MC-500 exhibited a set-to-touch time of 3 hours and a dry-through time of 15 hours.

### **Chemical Resistance (ASTM D1308)**

When exposed to selected reagents, paint thinner and gasoline, the MC-300 coating experienced some adhesion loss on the concrete surface (Figure 3) and complete adhesion loss on the steel surface (Figure 4); however, the MC-500 coating did not experience any blistering, discoloration, swelling, or other alterations on concrete (Figure 5) or steel (Figure 6) surfaces.

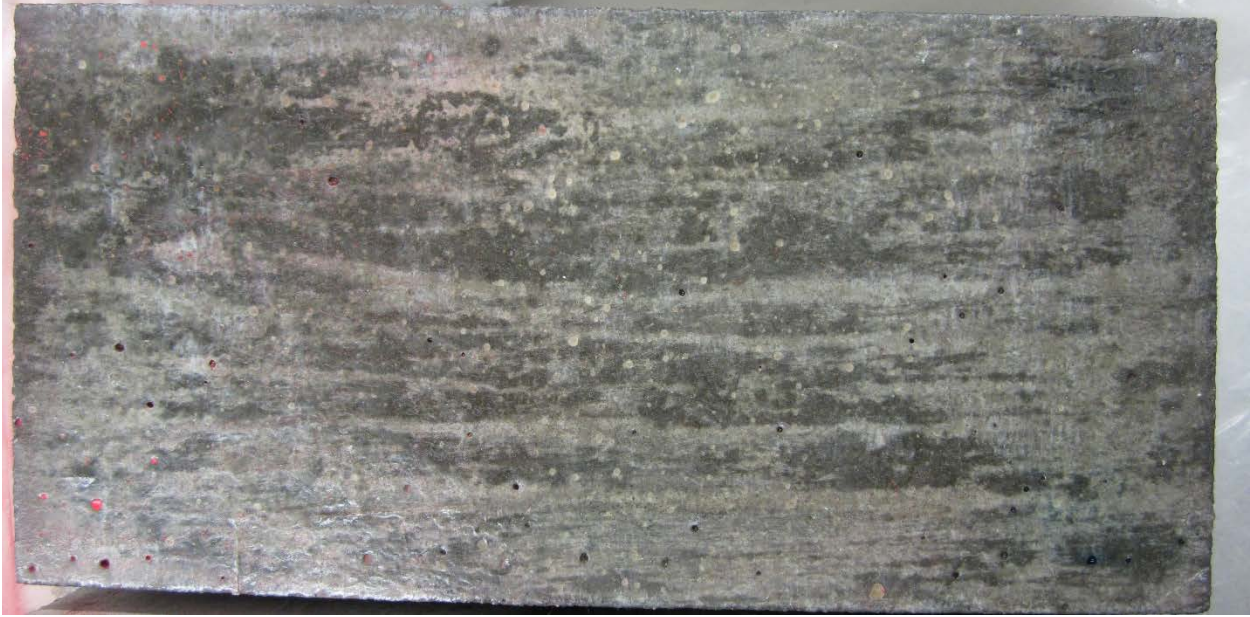


**Figure 3:** Chemical Resistance Test - MC-300 on concrete exposed to paint thinner and gasoline. Some adhesion loss.



**Figure 4:** Chemical Resistance Test - MC-300 on steel exposed to paint thinner and gasoline. Complete adhesion loss.





**Figure 5:** Chemical Resistance Test - MC-500 on concrete exposed to paint thinner and gasoline. No alterations.



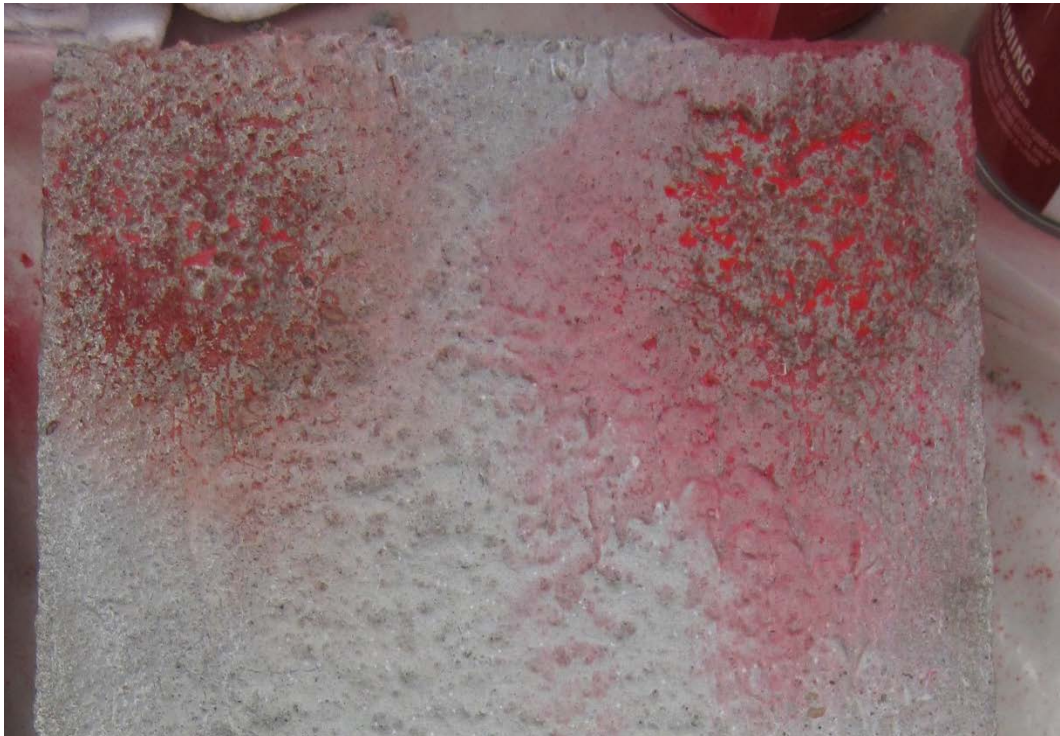
**Figure 6:** Chemical Resistance Test - MC-500 on steel exposed to paint thinner and gasoline. No alterations.

## **Graffiti Removal Using Chemical Testing (ASTM D6578)**

The following figures show the performance of Chemical Testing Graffiti Removal specimens as a function of number of test cycles for various types of graffiti markings. On each specimen, individual graffiti markings were rated for cleanability based on Table 1; markings considered “repellant” were recorded as “R” for graphical purposes.

### ***Concrete***

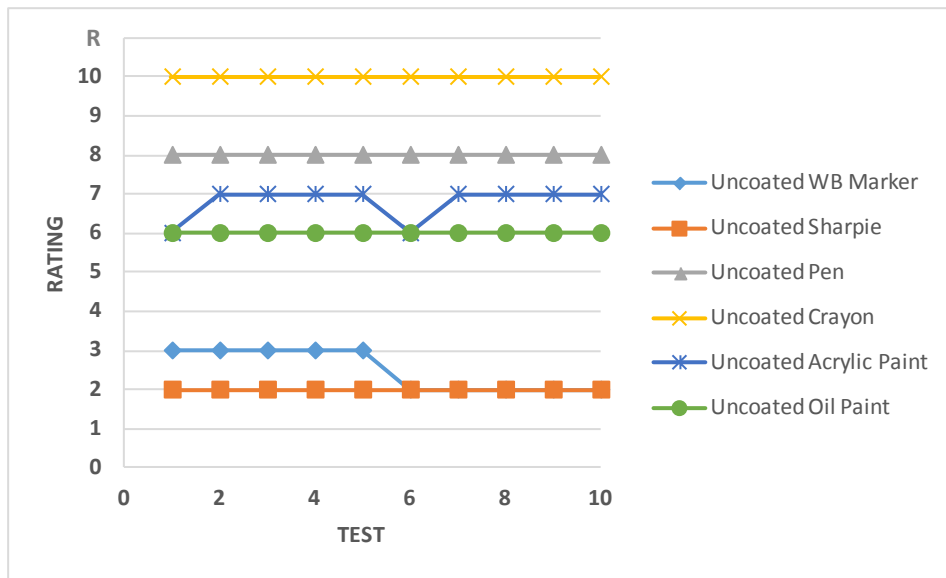
During the procedure, it was noticed that the rough surface of the concrete provided several crevices and voids for graffiti to reside as well as staining of the concrete surrounding the test square for various types of graffiti (Figure 7); therefore, the concrete was evaluated as clean as long as the graffiti was removed from the test square while the graffiti trapped in crevices or voids and the surrounding staining was disregarded. For clarification, the two test areas (acrylic spray paint-left, oil spray paint-right) shown in Figure 7 were considered to be cleanable.



**Figure 7:** Concrete crevices, voids, and surrounding stains



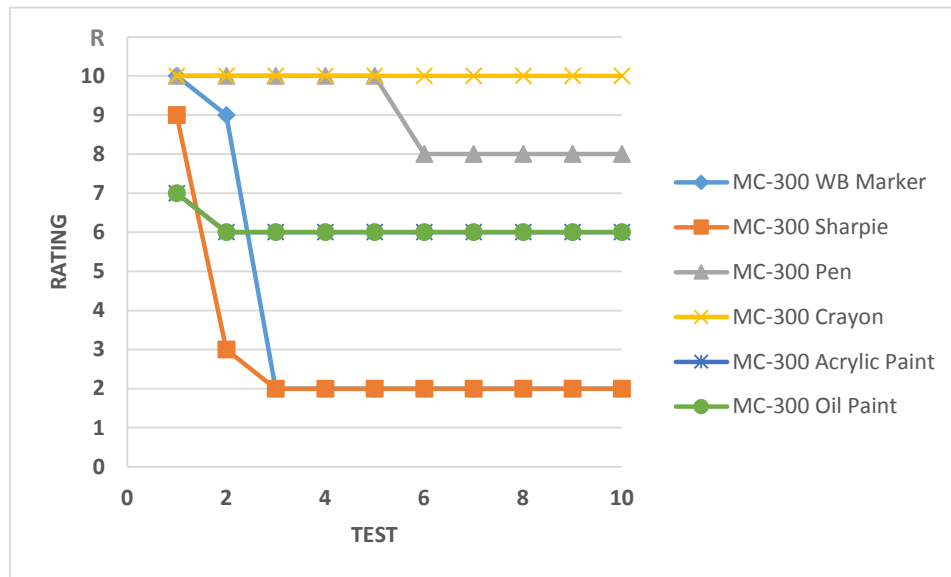
Figures 8 through 11 show the performance of uncoated, MC-300, recoated MC-300, and MC-500 concrete specimens, respectively. As shown in Figure 8, the uncoated concrete specimens had consistent results for removal of all graffiti types over all ten cycles. Crayon was the most readily removed graffiti type using a dry rag followed by ball point pen removed by isopropyl alcohol. The acrylic paint was typically able to be removed with mineral spirits, and oil paint was removed by xylene. The water-based and permanent markers were unable to be fully removed from the surface of the concrete for all cycles.



**Figure 8:** Performance of Uncoated Concrete Specimens

Figure 9 displays the performance of MC-300 coated concrete specimens. MC-300 specimens showed excellent cleanability for the first cycle; however, the abrasive action of rubbing the marks removed some of the coating. This resulted in a drastic drop in performance on subsequent cycles, particularly on the marks that required more effort to remove, such as permanent marker. Based on the figure, crayon and pen were the most readily removed types of graffiti. Crayon was consistently removed by a dry rag for all cycles while pen could be removed

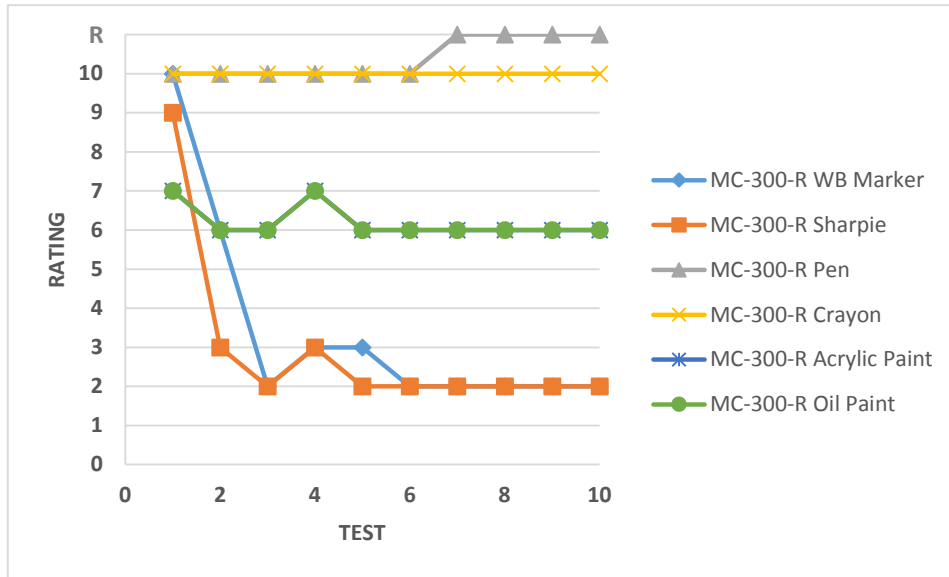
via dry rag for five cycles before requiring isopropyl alcohol to remove the remaining ink. Oil and acrylic spray paint were both able to be removed with mineral spirits for one cycle before consistently needing xylene to remove those types of graffiti for the outstanding cycles. The MC-300 coating allowed for removal of water-based marker and permanent marker for two cycles and one cycle, respectively, before they stained the concrete surface and were no longer cleanable. In general, the MC-300 was beneficial for one cycle before performance degraded to that of the uncoated specimens.



**Figure 9:** Performance of MC-300 Coated Concrete Specimens

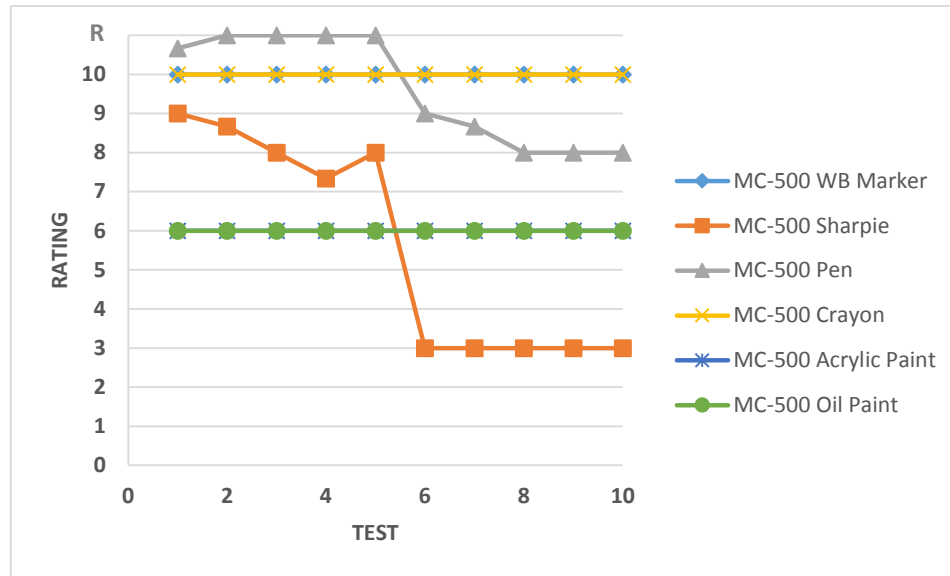
One concrete specimen was coated with MC-300 before the first test and reapplied prior to tests 4 and 7. The results shown in Figure 10 indicate that reapplication had minimal effect on the graffiti resistant qualities. Recoating the specimen was the most beneficial for protection against ball point pen, allowing removal via dry rag for several cycles and repelling the ink for the last four cycles. It also allowed oil and acrylic spray paint to be cleaned with mineral spirits for one cycle before performance declined. Crayon was removed with a dry rag for all cycles

regardless of the coating. The permanent and water-based markers were not able to be cleaned at all once they stained the concrete surface. Based on these results, MC-300 would need to be reapplied after each cleaning to provide complete protection.



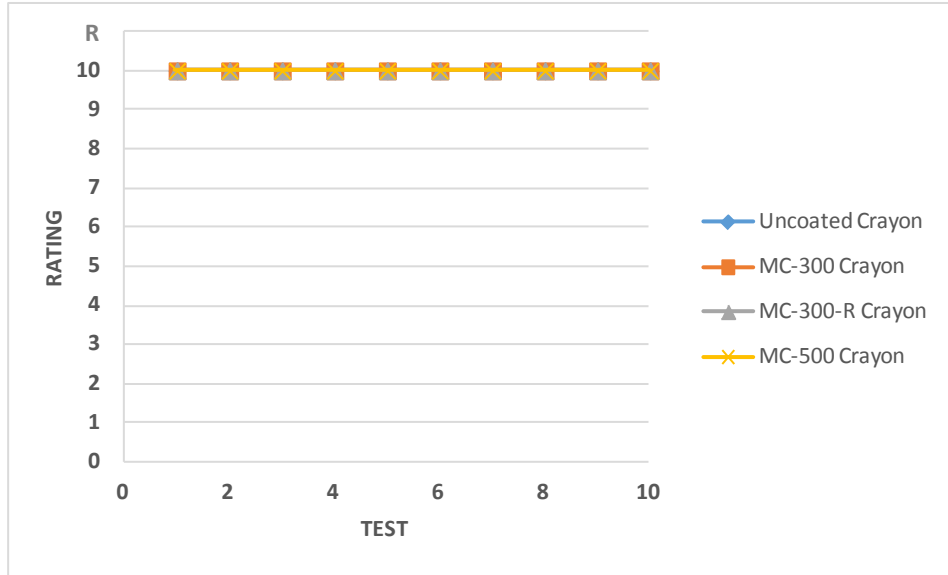
**Figure 10:** Performance of MC-300 Recoated Concrete Specimen

Figure 11 displays the average performance of MC-500 coated concrete specimens. Crayon and water-based marker were most readily removed using a dry rag for all cycles. Ball-point pen was repellent for five cycles before declining for the remaining cycles requiring isopropyl alcohol for removal. Oil and acrylic spray paint were cleanable with xylene for all ten cycles. Sharpie was cleanable with a variety of cleaning agents until the sixth cycle, after which it was no longer cleanable.

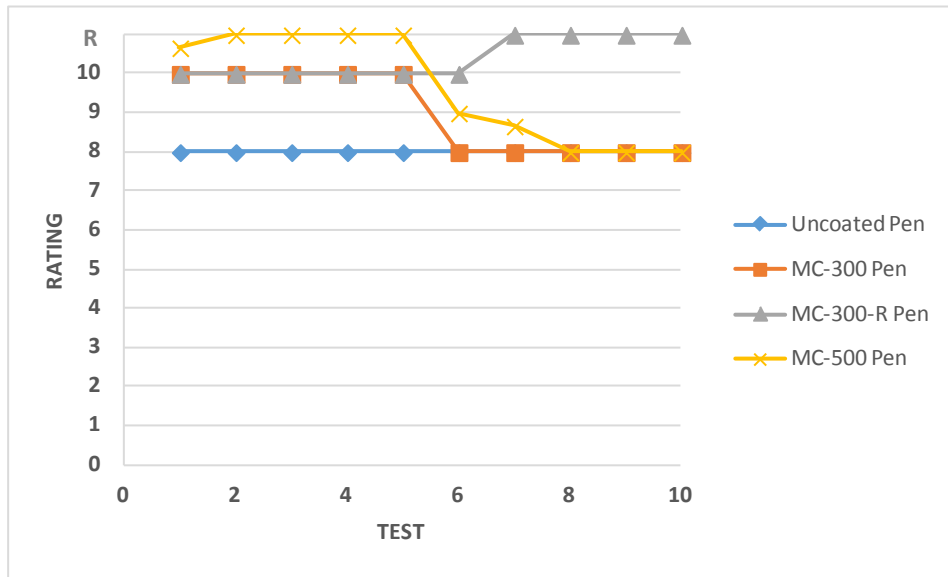


**Figure 11: Performance of MC-500 Coated Concrete Specimens**

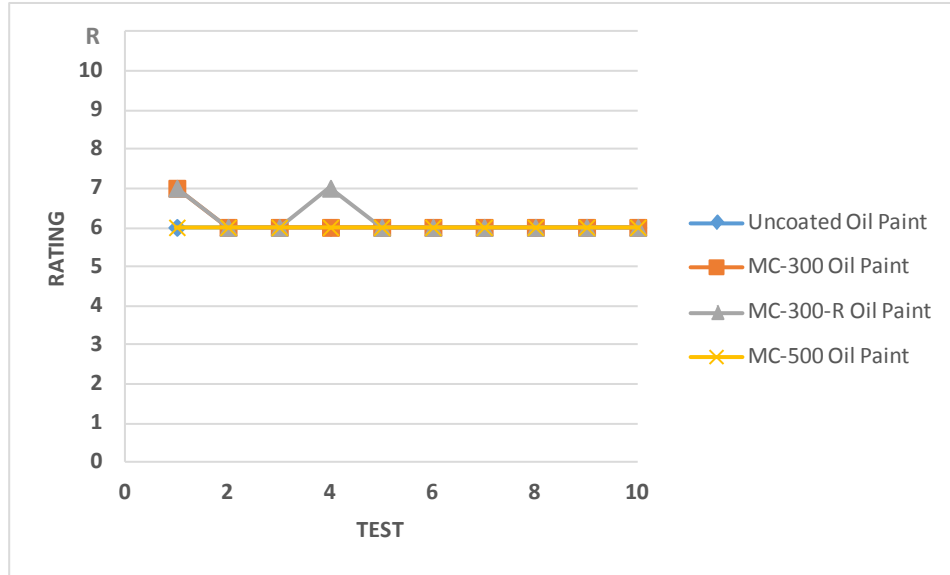
A comparison of coating resistance to individual types of graffiti is shown in Figures 12-17. As shown in Figure 12, crayon was removable via dry rag for all cycles regardless of coating type. Based on Figure 13, MC-500 performed the best against pen for seven cycles where it was repellant for the first five tests; however, pen was able to be cleaned with a dry rag on the MC-300 coated specimens for five cycles, and recoating the specimen created a repellant barrier for the remaining four cycles. Oil paint was slightly easier to remove using mineral spirits when applied to the MC-300 coated and MC-300 recoated concrete specimens for one cycle (Figure 14). After one cycle, all concrete specimens required xylene to remove oil paint. Figure 15 displays uncoated specimens had the best performance against acrylic spray paint. Figure 16 depicts MC-500 coated specimens were the only specimens where water-based marker was cleanable for all cycles. In addition, MC-500 coated specimens had high resistance to permanent marker which was cleanable for five cycles (Figure 17). In general, the MC-500 coating had the best performance for graffiti removal using solvents on concrete specimens.



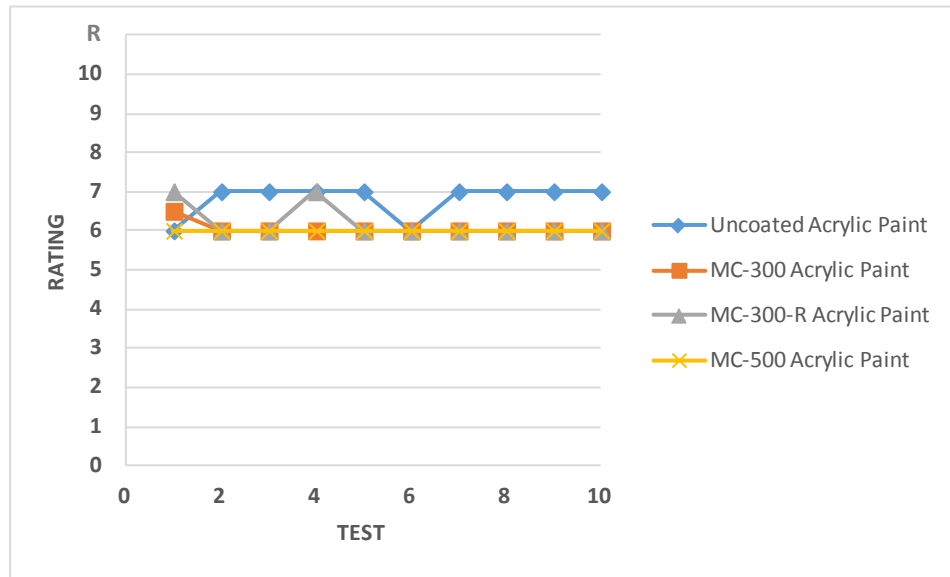
**Figure 12:** Graffiti Resistance against Crayon



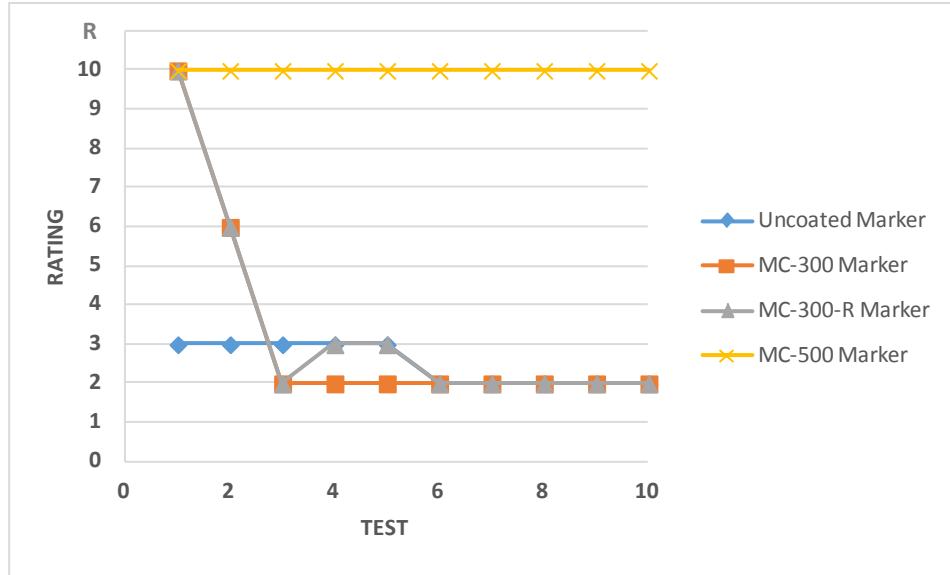
**Figure 13:** Graffiti Resistance against Pen



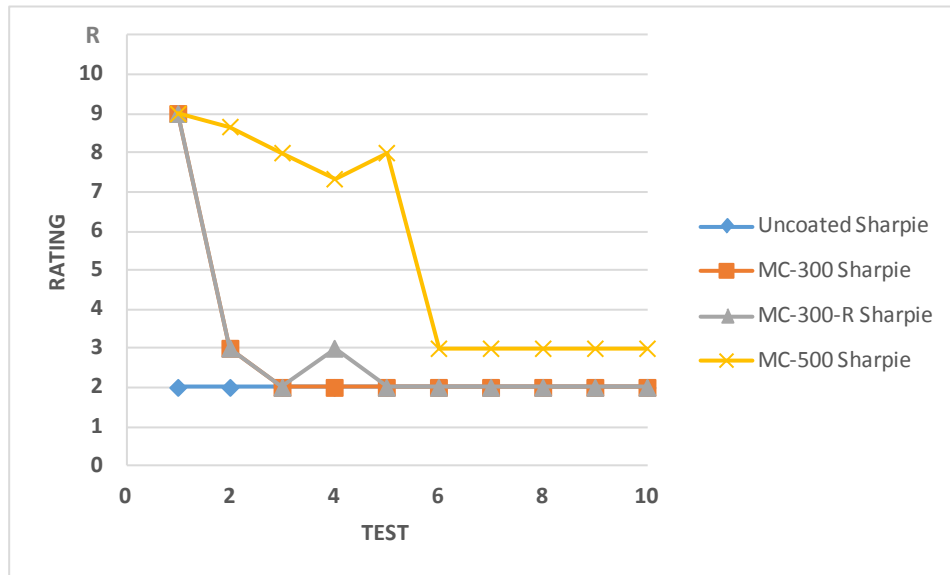
**Figure 14:** Graffiti Resistance against Oil Paint



**Figure 15:** Graffiti Resistance against Acrylic Paint



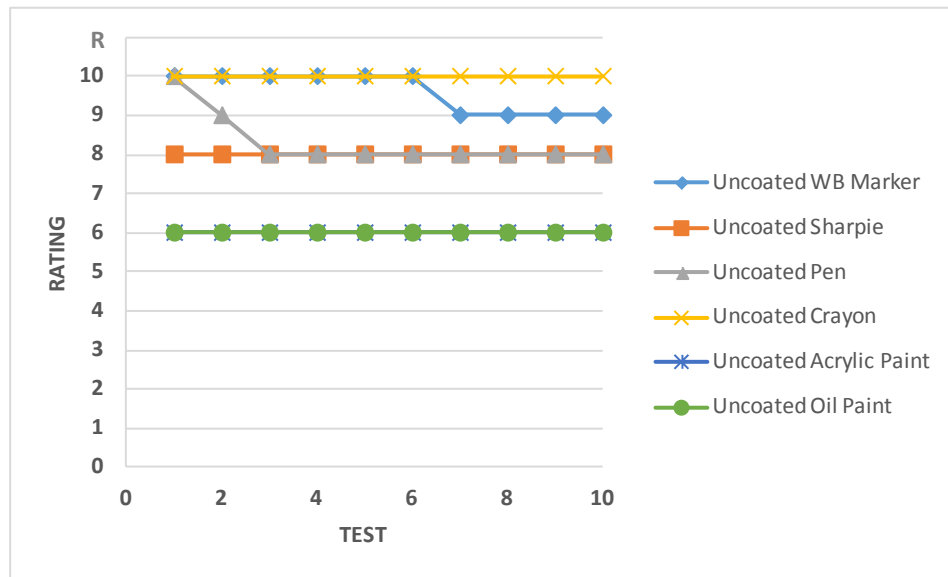
**Figure 16:** Graffiti Resistance against Water-Based Marker



**Figure 17:** Graffiti Resistance against Sharpie

## Steel

Figures 18 through 22 show the performance of uncoated, MC-300, recoated MC-300, and MC-500 steel specimens, respectively. Based on Figure 18, every type of graffiti was consistently cleanable for all cycles. Crayon was the most readily cleanable using only a dry rag. Water-based marker was cleanable with a dry rag for six cycles before declining slightly to removal via detergent. Sharpie and pen were removed using isopropyl alcohol for all cycles. Acrylic and oil spray paint were removed by xylene.

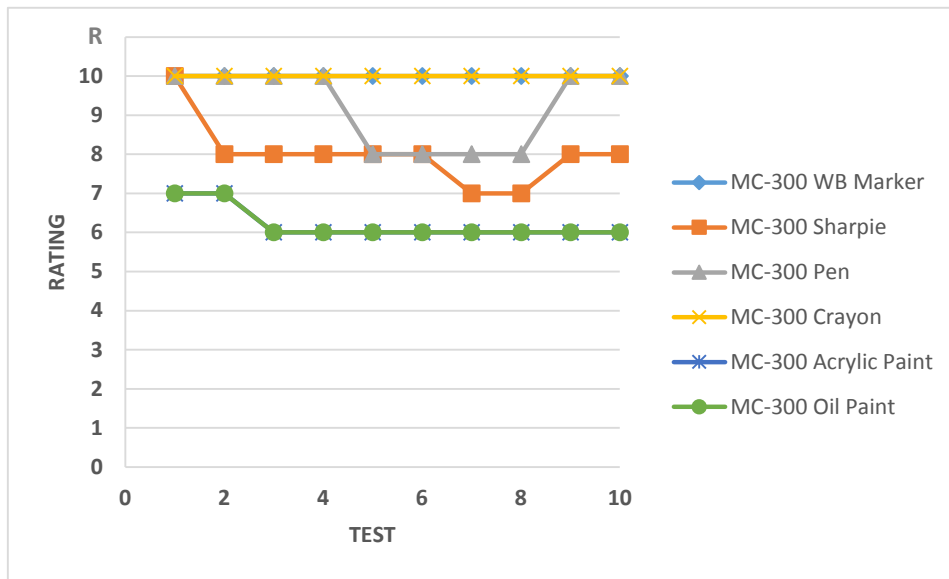


**Figure 18:** Performance of Uncoated Steel Specimens

Figure 19 displays the performance of MC-300 coated specimens. From the figure, it can be seen that crayon and water-based marker were removed via dry rag for all ten cycles. Pen was able to be removed with a dry rag for four cycles before declining to removal using isopropyl alcohol. Sharpie was removed with a dry rag for one cycle and then was only removed by isopropyl alcohol and even mineral spirits for the remaining cycles. Oil and acrylic paint were removed with mineral spirits for two cycles, and then resembled uncoated specimen performance



for the remaining cycles. During the procedure, the aggressive scrubbing of the graffiti and various chemicals, such as mineral spirits and xylene, removed the MC-300 from the surface of the steel. Once the coating wore off, the performance was similar to an uncoated specimen. An example of the wear can be seen in Figure 20.

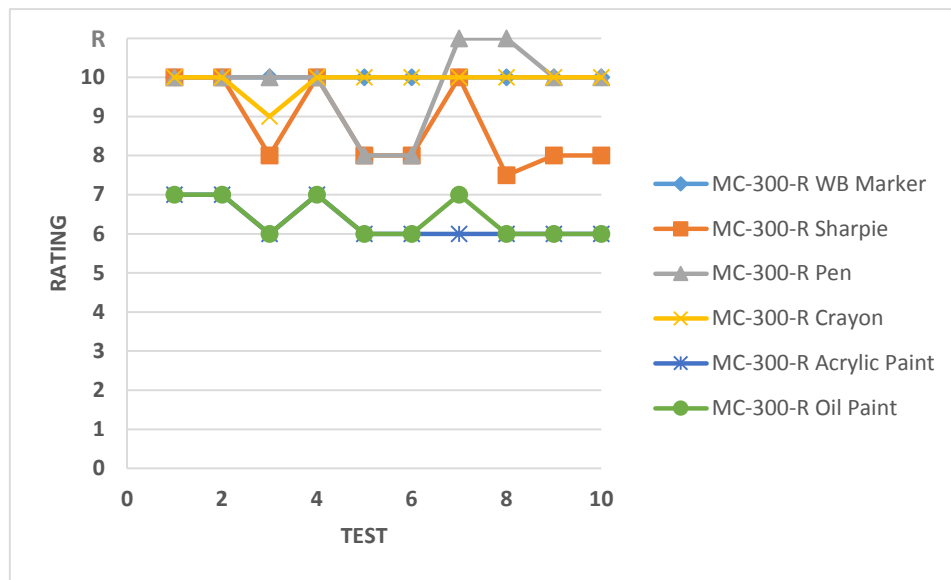


**Figure 19:** Performance of MC-300 Coated Steel Specimens



**Figure 20:** Wear on MC-300 coating after 10 cycles

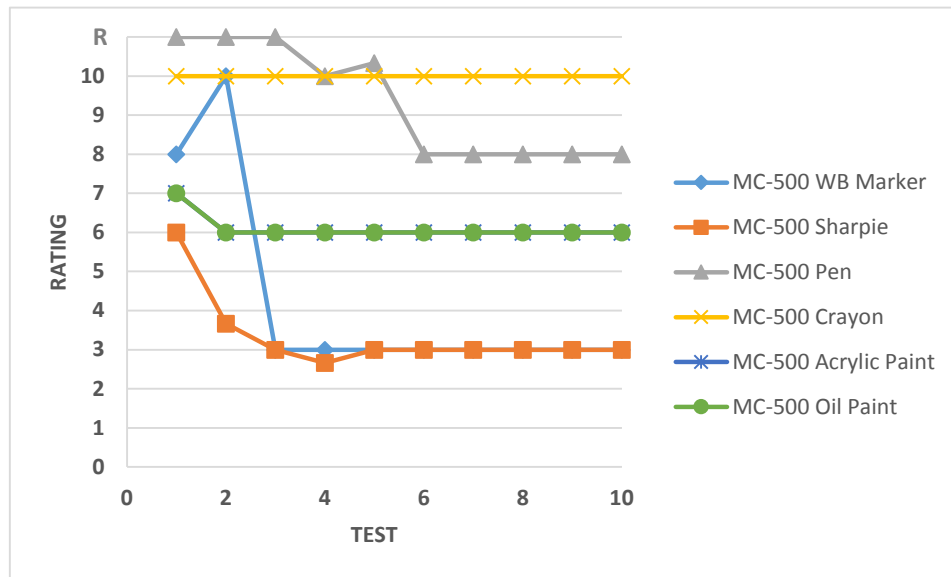
Due to the excessive wear of the MC-300 coating, two steel specimens were coated with MC-300 before the first test and recoated prior to tests 2, 4, and 7. The results shown in Figure 21 indicate that reapplication restored most of the graffiti resistant qualities. Recoating the specimen was the most beneficial for protection against permanent marker, allowing removal via dry rag for the cycle after reapplication. Resistance against ball-point pen was also restored by every reapplication of the coating. Oil and acrylic spray paint were able to be cleaned with mineral spirits for one cycle after reapplication before declining back to performance comparable to uncoated specimens. Crayon and water-based marker were removed with a dry rag regardless of the coating. Based on these results, MC-300 would need to be reapplied after each cleaning to maintain full graffiti resistance.



**Figure 21:** Performance of MC-300 Recoated Steel Specimens

Figure 22 shows the performance of MC-500 coated steel specimens. As displayed in the figure, crayon was removable with a dry rag for all ten cycles. Pen was repellent for three cycles before it made a continuous mark, which was removable with a dry rag, for two cycles. After

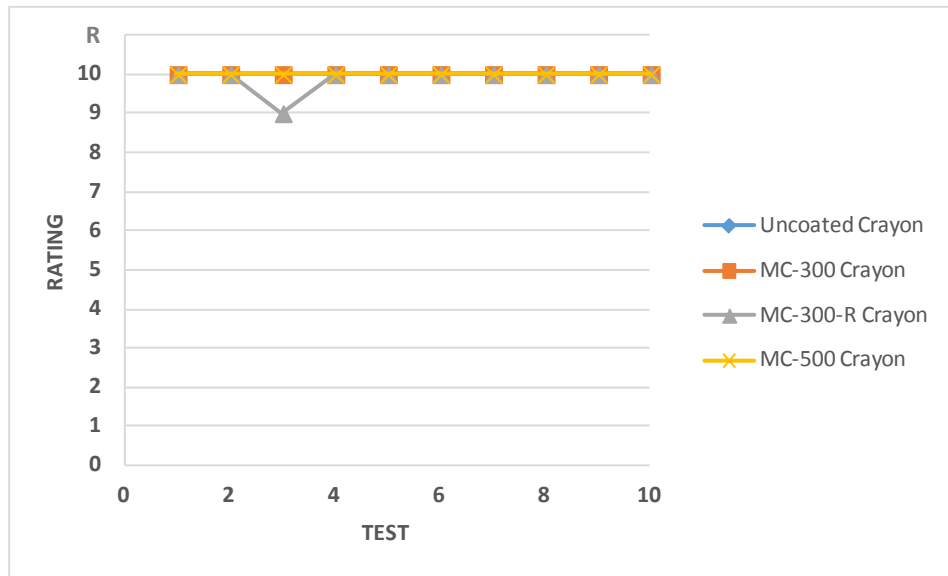
that, isopropyl alcohol was needed to remove the pen. Oil and acrylic paint were both removable with mineral spirits for one cycle; xylene was needed to remove those types of graffiti for subsequent cycles. The water-based marker was removable for two cycles before it stained the MC-500 coating and was no longer removable. Permanent marker was only cleanable with xylene for one cycle. Although the MC-500 coating was more durable than the MC-300 coating, it was noticed that the harsher chemicals such as xylene and methyl ethyl ketone combined with abrasive scrubbing of the graffiti broke down and thinned the MC-500 coating.



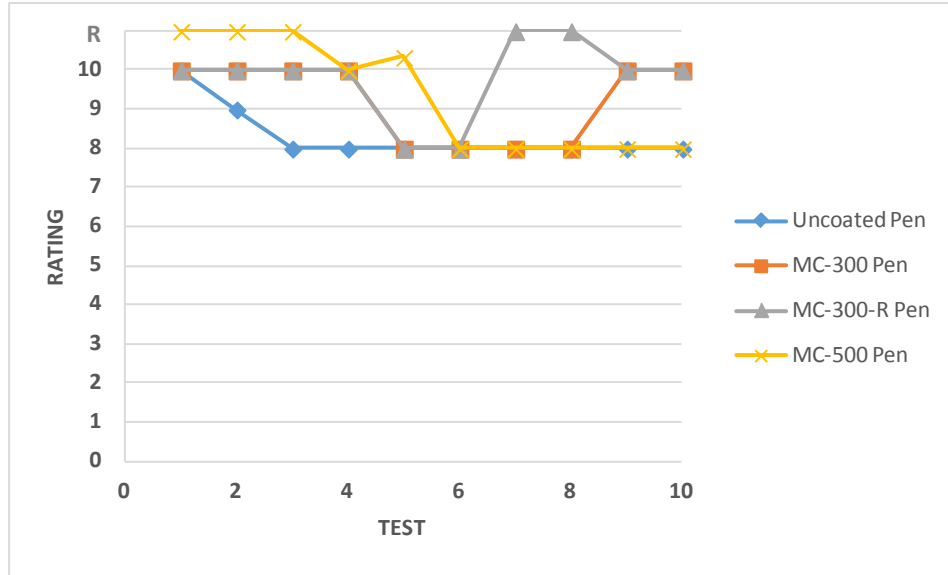
**Figure 22:** Performance of MC-500 Coated Steel Specimens

A comparison of coating resistance to individual types of graffiti is shown in Figures 23-28. As shown in Figure 23, crayon was removable from the steel specimens via dry rag for all cycles regardless of any type of coating. Based on Figure 24, in comparison to uncoated steel specimens, both MC-300 and MC-500 enhanced graffiti resistance against pen. MC-500 performed the best against pen for the first three cycles where it was repellent; however after three cycles, a dry rag was used to clean the pen marking for an additional two cycles before performance declined resembling uncoated specimen performance. Pen was cleanable with a dry

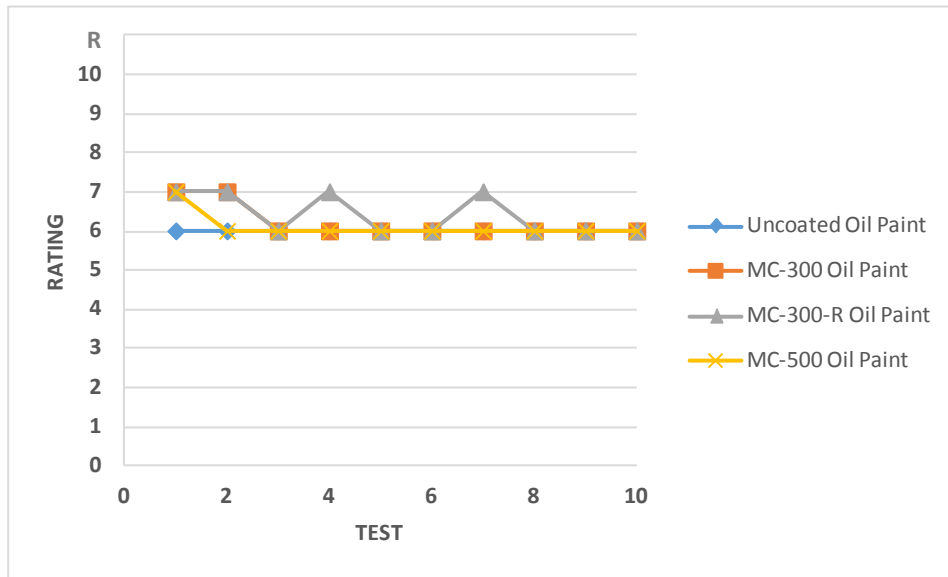
rag on the MC-300 coating for four cycles before declining to cleanability similar to uncoated specimens. Figures 25 and 26 display that both oil and acrylic spray paint were slightly easier to remove when applied to the MC-300 and MC-500 coated steel specimens. Oil and acrylic paint applied to MC-300 coated steel were cleanable with mineral spirits for two cycles, whereas oil and acrylic paint applied to MC-500 coated steel were cleanable with mineral spirits for one cycle. After that, all steel specimens required xylene to remove oil paint. Figure 27 depicts MC-300 coated specimens performed somewhat better than uncoated specimens against water-based marker, cleanable with only a dry rag for all ten cycles. Additionally, MC-300 coated specimens improved resistance to permanent marker where the sharpie was cleanable for one cycle with a dry rag before isopropyl alcohol was needed (Figure 28). In summary, even though MC-300 had the best graffiti resistance of the three systems tested, the MC-300 coating on steel only performed slightly better than uncoated steel, though reapplying the coating could improve performance.



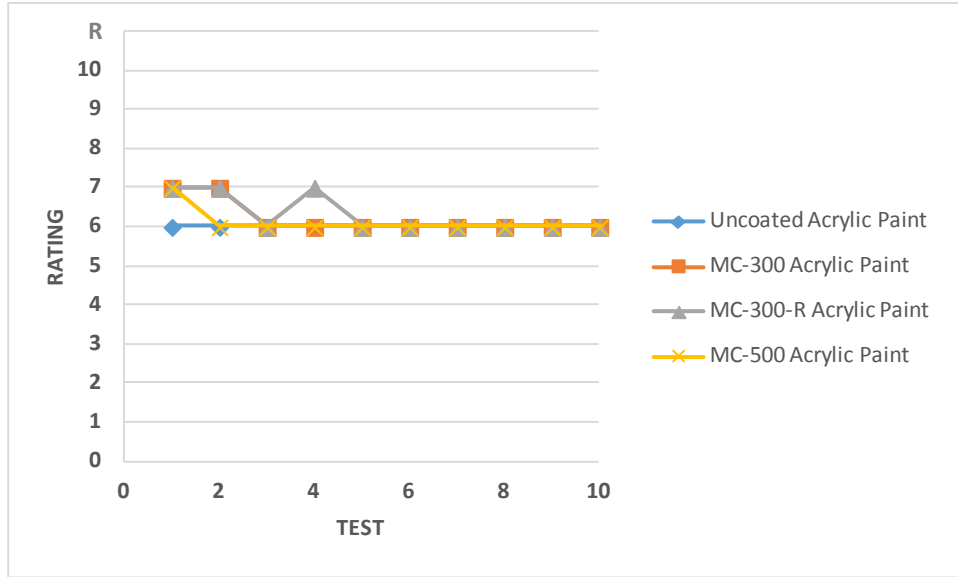
**Figure 23:** Graffiti Resistance against Crayon



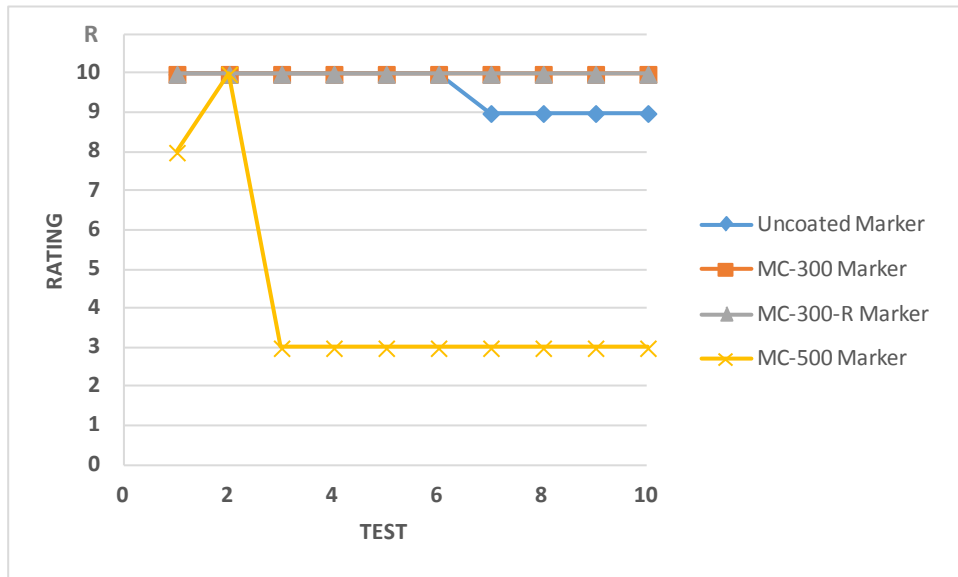
**Figure 24:** Graffiti Resistance against Pen



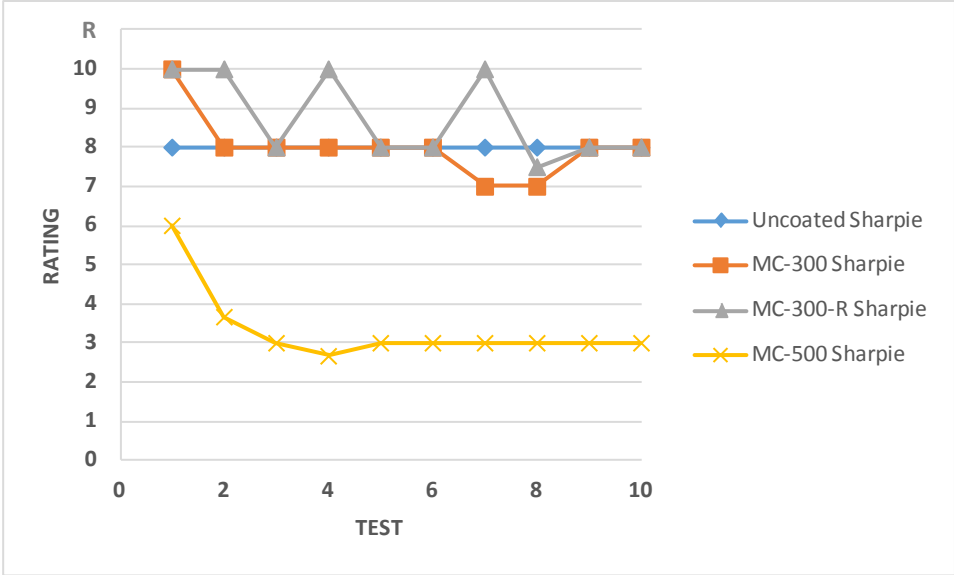
**Figure 25:** Graffiti Resistance against Oil Paint



**Figure 26:** Graffiti Resistance against Acrylic Paint



**Figure 27:** Graffiti Resistance against Water-Based Marker



**Figure 28:** Graffiti Resistance against Sharpie

## **Graffiti Removal Using Pressure Washer (ASTM D7089)**

This section describes the performance of pressure washing specimens as a function of number of test cycles. The percentage of graffiti removed using only a cold pressure wash is indicated by the blue column on each test cycle. The orange portion of the column represents the additional percentage of graffiti removed using a commercial graffiti remover combined with pressure washing. The total percentage of graffiti removed is indicated by the total height of the column.

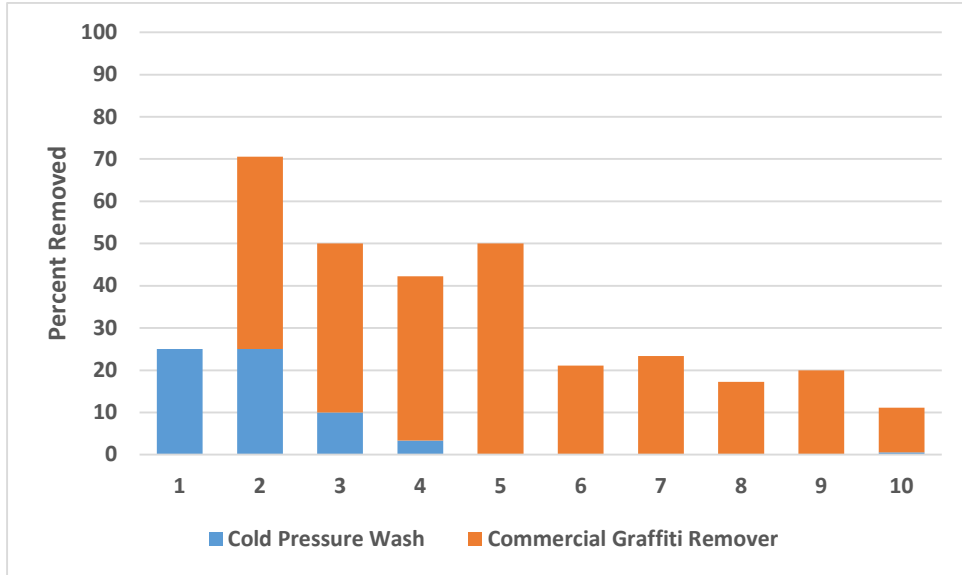
The levels of cleanability were determined using the average percentage of each type of graffiti removed for each set of specimens. Due to rough surface texture, voids, and testing variability, it was virtually impossible to remove exactly 100% of the graffiti from the specimen. Therefore, the surface was considered “clean” when at least 90% of the graffiti was removed. The cleanability levels are defined as follows: Any blue column that surpassed 90% graffiti removal was evaluated as Cleanability Level 1 for that cycle. Any orange column that exceeded 90% graffiti removal utilizing the commercial graffiti remover was labeled as Cleanability Level 2 for that cycle. If the total column height was less than 90%, the specimen was considered to be “not cleanable” and was beyond the scope of this project. Furthermore, the cleanability levels were evaluated and reported with the number of cleanable cycles until the specimen was no longer cleanable.

### ***Concrete***

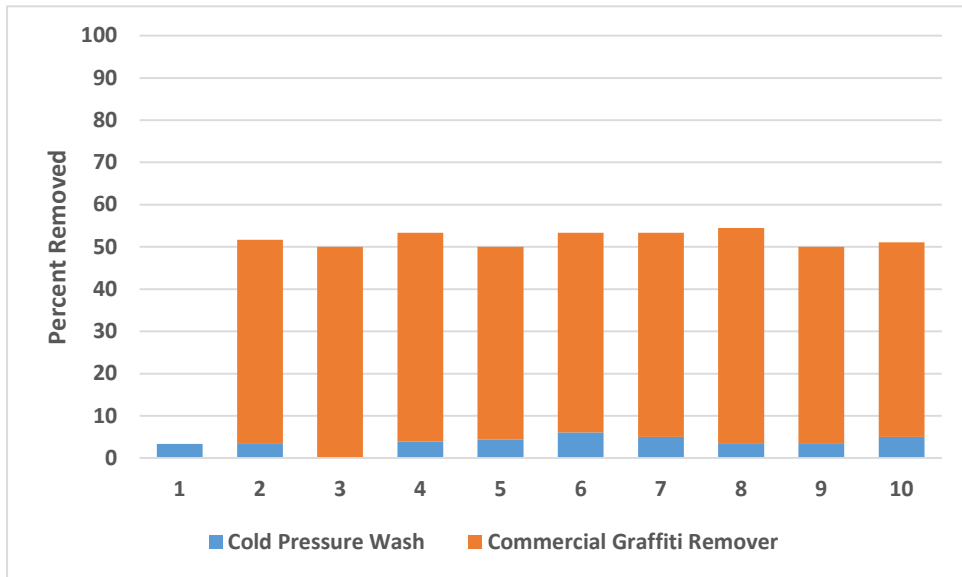
Figures 29 to 32 show the average performance of uncoated, MC-300, recoated MC-300, and MC-500 specimens, respectively. As a note, commercial graffiti remover was not utilized on the concrete specimens until the second test cycle; therefore, the first cycle of the concrete



pressure washing specimens do not have the orange column. Based on Figure 29, the uncoated specimens were unable to be fully cleaned, either with the pressure washer alone or the commercial graffiti remover. Performance against spray paint (Figure 29a) declined as the number of cycles of testing increased; however, the performance against permanent marker remained consistent removing a total of approximately 50% of the permanent marker for the remaining cycles (Figure 29b). Based on the performance for both types of graffiti, uncoated concrete specimens did not meet requirements of Cleanability Level 1 or 2 for either type of graffiti and were rated as not cleanable for all cycles.

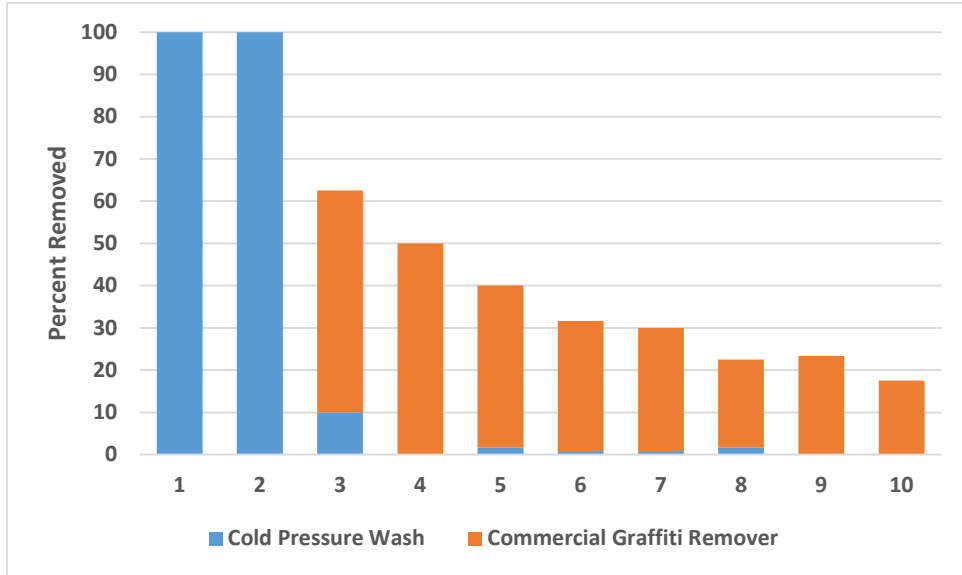


**Figure 29a:** Performance of Uncoated Concrete Specimens - Spray Paint

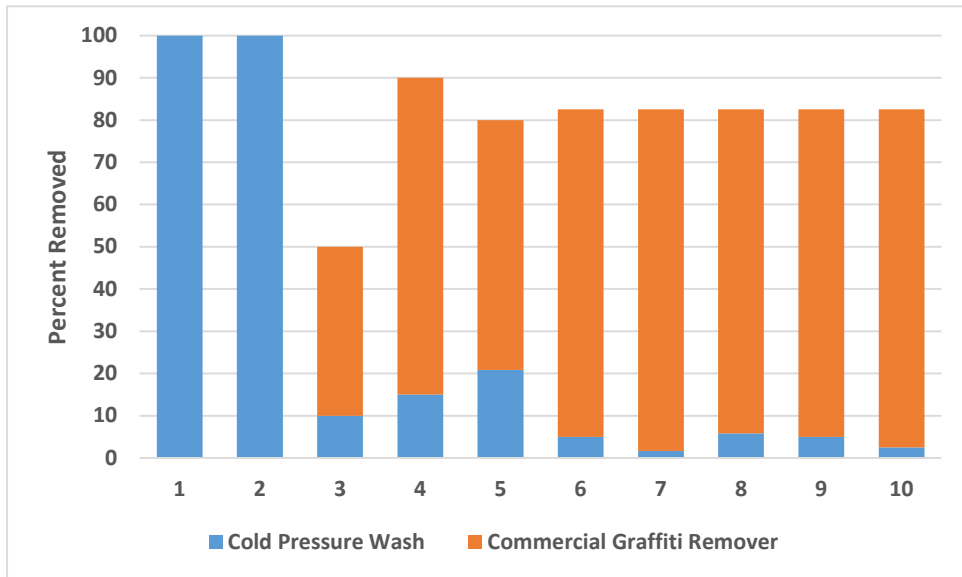


**Figure 29b:** Performance of Uncoated Concrete Specimens - Permanent Marker

MC-300 specimens that were not recoated (Figure 30) were able to be fully cleaned with the cold-water pressure wash; however, the coating was partially removed by this process. After two cycles, the coating was sufficiently removed resulting in declination of performance. The MC-300 coating performance against spray paint (Figure 30a) after two cycles resembled the results obtained for uncoated specimens of the same magnitude and trend. The MC-300 performance against permanent marker (Figure 30b) after two cycles remained consistent removing a total of approximately 80% for the remaining cycles. For both types of graffiti, the MC-300 coated concrete specimens were rated as Cleanability Level 1 for two cycles.



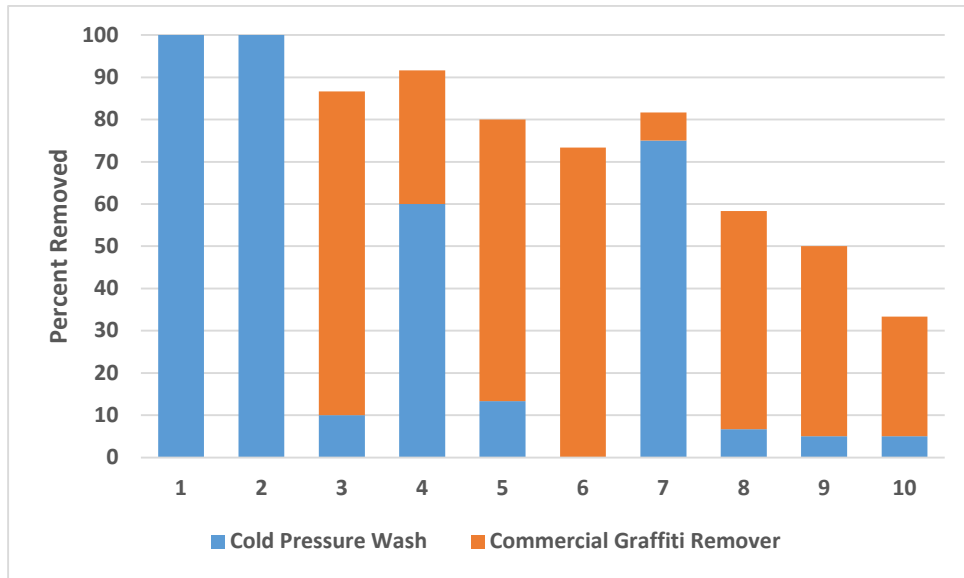
**Figure 30a:** Performance of MC-300 Concrete Specimens - Spray Paint



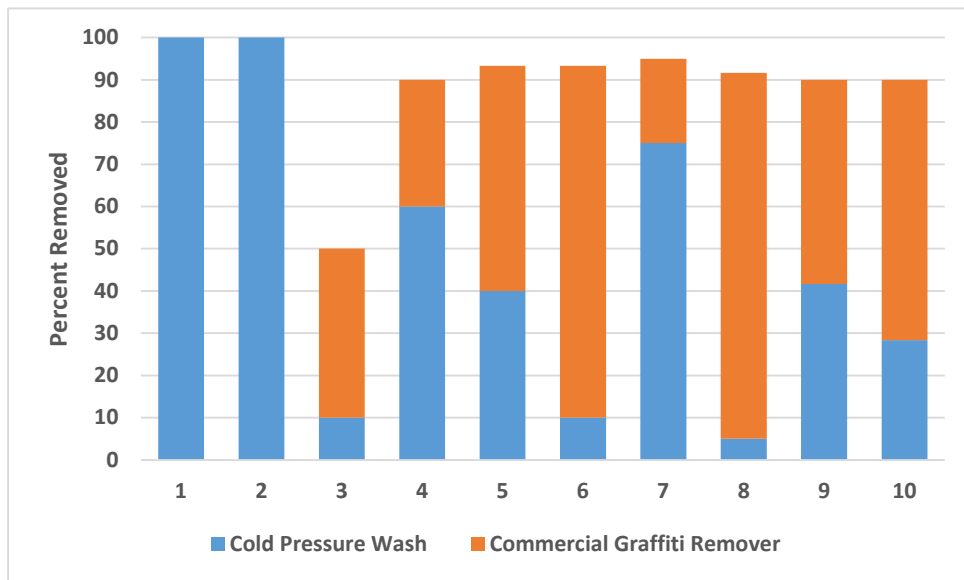
**Figure 30b:** Performance of MC-300 Concrete Specimens - Permanent Marker

One MC-300 specimen was coated before the first test and then recoated prior to cycles 4 and 7 to assess the effects of reapplication. Although the results shown in Figures 31a and 31b indicate that reapplication of the MC-300 coating restored most of the graffiti resistant capabilities, especially for the cold-pressure wash alone, reapplication does not fully restore those capabilities. The recoated MC-300 concrete specimen was evaluated as Cleanability Level 1 for the first two cycles only.

There are a few possible reasons as to why graffiti resistant capabilities were not fully restored. First, the pressure washer partially removed the MC-300 coating which allowed for graffiti of subsequent cycles to adhere to the concrete itself, resulting in performance similar to uncoated specimens. Second, the MC-300 coating was reapplied over the leftover graffiti from previous cycles, which would prevent the removal of old graffiti in subsequent cycles. Last, the pressure washer removed cement paste at the surface of the specimen. This could result in cavities where it is difficult to get a full and even coating of the MC-300 and also provide areas that are difficult to remove graffiti from on subsequent cleanings.

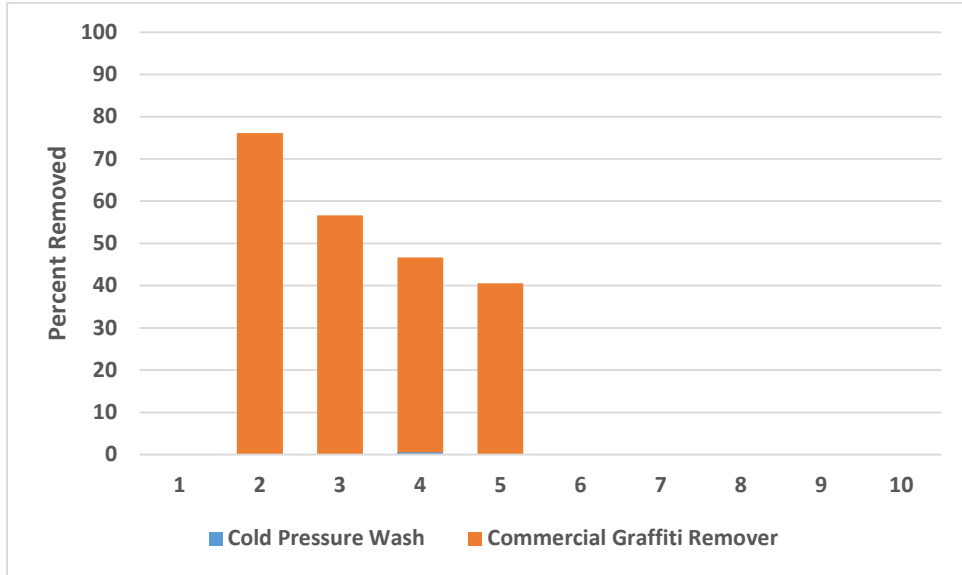


**Figure 31a:** Performance of Recoated MC-300 Concrete Specimen - Spray Paint

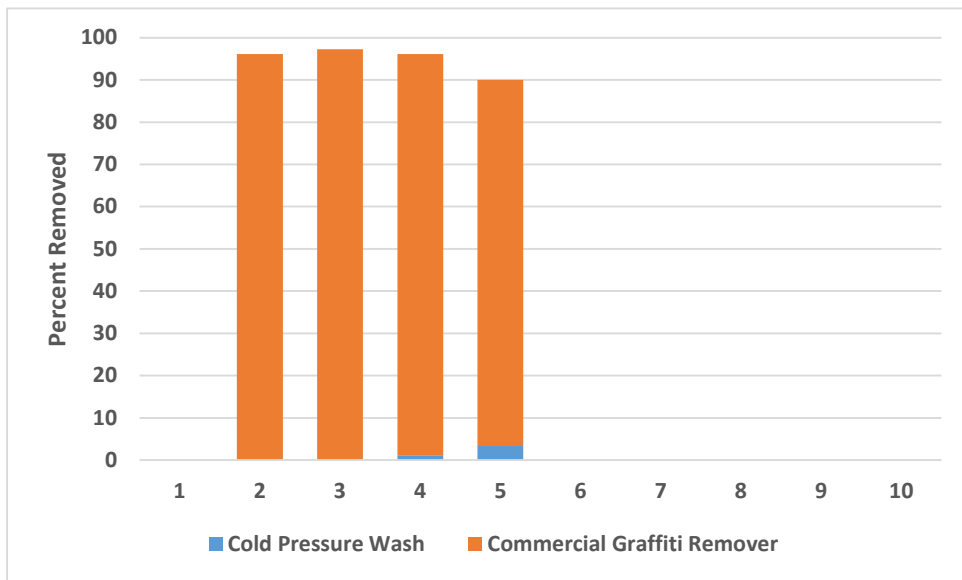


**Figure 31b:** Performance of Recoated MC-300 Concrete Specimen - Permanent Marker

The performance of MC-500 coated concrete specimens are shown in Figure 32. As stated, the first cycle did not utilize the commercial graffiti remover as indicated by the orange column. Additionally, the MC-300 coated specimens were not able to be cleaned with the cold-water wash alone, resulting in a blank column for the first cycle. It was observed that utilizing the commercial graffiti remover on subsequent cycles resulted in spray paint removal comparable to the uncoated specimens and near complete removal of the permanent marker. Testing was discontinued after the fifth cycle due to the MC-500 coating consistently performing worse than the uncoated specimens after cold-water wash alone. The MC-500 coating was more durable than the MC-300; however, moderate wear was noticed after five cycles including thinning of the MC-500 coating and appearance of holes on the surface. The MC-500 coated concrete specimens were rated as not cleanable for spray paint (Figure 32a) and Cleanability Level 2 for five cycles for permanent marker (Figure 32b).



**Figure 32a:** Performance of MC-500 Concrete Specimens - Spray Paint

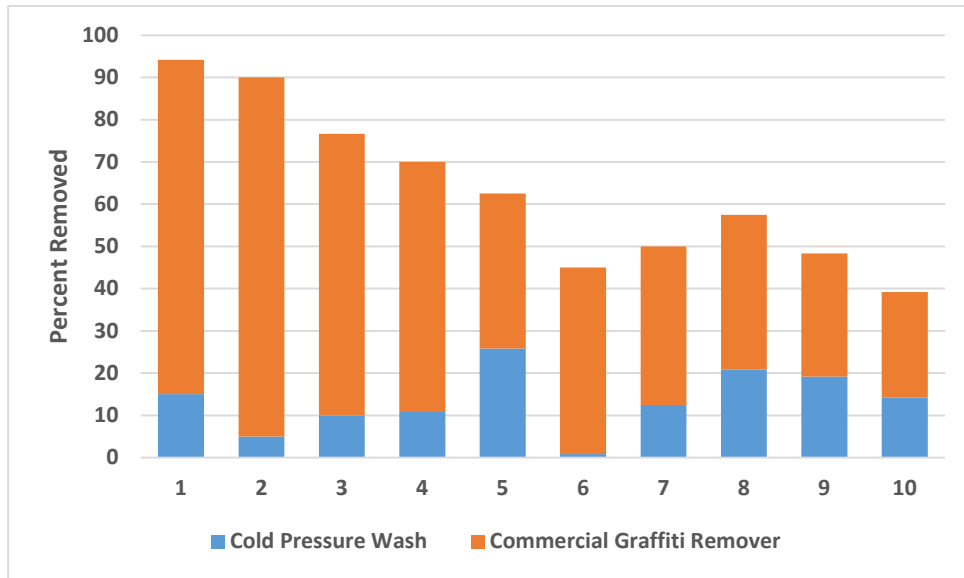


**Figure 32b:** Performance of MC-500 Concrete Specimens - Permanent Marker

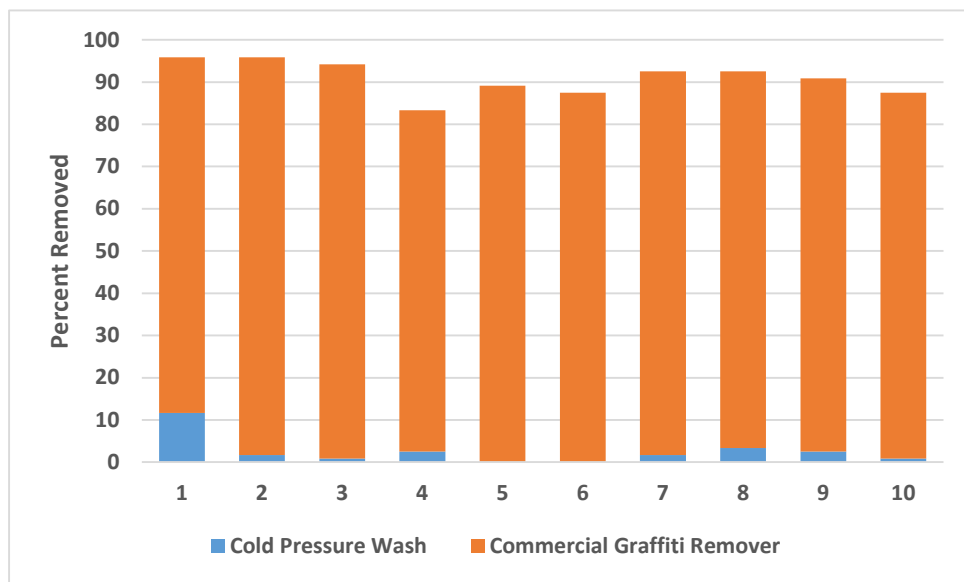


## *Steel*

Figures 33 and 34 show the performance of uncoated and MC-300 specimens as a function of number of test cycles. Uncoated specimens (Figure 33) were unable to be fully cleaned with the pressure washer alone; near complete removal was obtained with the commercial graffiti remover, although the effectiveness decreased as the number of test cycles increased. As was observed on the concrete specimens, performance against spray paint (Figure 33a) declined as the number of cycles of testing increased; the performance against permanent marker (Figure 33b) remained consistent resulting in approximately 90% of total graffiti removal through the duration of the test cycles. The uncoated steel specimens were rated as Cleanability Level 2 for two cycles of spray paint and Cleanability Level 2 for three cycles of permanent marker.

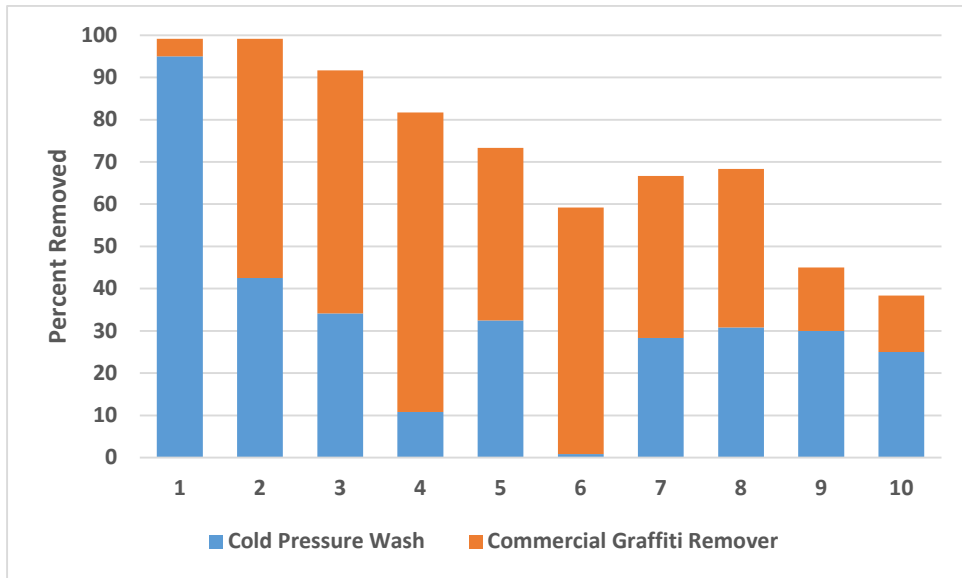


**Figure 303a:** Performance of Uncoated Steel Specimens - Spray Paint

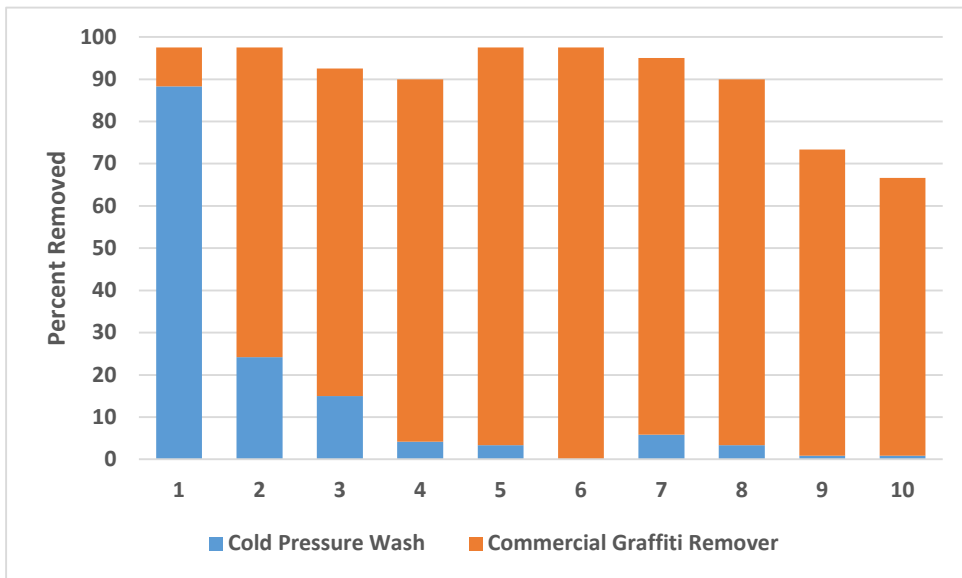


**Figure 33b:** Performance of Uncoated Steel Specimens - Permanent Marker

MC-300 specimens (Figure 34) were able to be fully cleaned with the cold-water pressure wash; however, the coating was partially removed by this process. After one cycle, the coating was sufficiently removed that performance declined. After three cycles, the MC-300 specimens performed comparably to uncoated specimens. Based on Figure 34a, the MC-300 coated steel specimens were rated as Cleanability Level 1 for one cycle and Cleanability Level 2 for an additional two cycles of spray paint. As depicted in Figure 34b, the MC-300 coated steel specimens were rated as Cleanability Level 2 for eight cycles of permanent marker. A photo comparison of uncoated and MC-300 specimens during the second and tenth cycle of the pressure-wash test are shown in Figures 35a and 35b, respectively.



**Figure 34a:** Performance of MC-300 Steel Specimens - Spray Paint



**Figure 34b:** Performance of MC-300 Steel Specimens - Permanent Marker



**Figure 31a:** Pressure Washer Test - 2nd Cycle. Uncoated steel (top) and steel coated with MC-300 (bottom).



**Figure 35b32:** Pressure Washer Test - 10th Cycle. Uncoated steel (top) and steel coated with MC-300 (bottom).

## SUMMARY OF RESULTS

This project investigated various properties of MicroCor-300 and MicroCor-500 coatings on steel and concrete surfaces. The coatings were evaluated for time of set, chemical resistance, and graffiti resistance. The results of all tests performed are summarized in the following tables. Table 3 displays the results of the time of set for MC-300 and MC-500 coatings, indicating MC-300 had a much faster drying time than the MC-500 coating.

**Table 3: Time-of-Set Results**

	<b>MC-300</b>	<b>MC-500</b>
<b>Set-To-Touch</b>	15 minutes	3 hours
<b>Dry-Through</b>	1.5 hours	15 hours

Table 4 displays the results of MC-300 and MC-500 for chemical resistance on steel and concrete. While MC-500 exhibited no alterations, the MC-300 coating lost adhesion to the substrates.

**Table 4: Chemical Resistance Results**

	<b>MC-300</b>		<b>MC-500</b>	
	<b>Steel</b>	<b>Concrete</b>	<b>Steel</b>	<b>Concrete</b>
<b>Paint Thinner</b>	Full adhesion loss	Some adhesion loss	No alterations	No alterations
<b>Gasoline</b>	Full adhesion loss	Some adhesion loss	No alterations	No alterations

Tables 5a and 5b show the graffiti resistance results for uncoated, MC-300, and MC-500 specimens on concrete and steel substrates, respectively. The tables summarize the maximum level of cleanability with the corresponding number of repeatable cycles as well as the last level of cleanability and its last cleanable cycle for Chemical Testing and Pressure Washing specimens. In the tables, the highest level of cleanability is listed first followed by the last level of cleanability and separated by a forward slash i.e. maximum cleanability / last cleanability.

Similarly, the repeatability is defined as follows: number of cycles for maximum cleanability / last cleanable cycle. Results showing one number indicate consistent results throughout the duration of the test.

**Table 5a: Graffiti Resistance Results on Concrete Substrates**

	Uncoated (Concrete)		MC-300 (Concrete)		MC-500 (Concrete)	
	Cleanability	Repeatability	Cleanability	Repeatability	Cleanability	Repeatability
<b>Chemical Testing</b>						
Water-Based Marker	Not Cleanable	-	10 / 9	1 / 2	10	10
Permanent Marker	Not Cleanable	-	9	1	9 / 7	1 / 5
Pen	8	10	10 / 8	5 / 10	R / 8	5 / 10
Crayon	10	10	10	10	10	10
Acrylic Paint	7	10	7 / 6	1 / 10	6	10
Oil Paint	6	10	7 / 6	1 / 10	6	10
<b>Pressure Washing</b>						
Spray Paint	Not Cleanable	-	1	2	Not Cleanable	-
Permanent Marker	Not Cleanable	-	1	2	2	5

**Table 5b: Graffiti Resistance Results on Steel Substrates**

	Uncoated (Steel)		MC-300 (Steel)		MC-500 (Steel)	
	Cleanability	Repeatability	Cleanability	Repeatability	Cleanability	Repeatability
<b>Chemical Testing</b>						
Water-Based Marker	10 / 9	6 / 10	10	10	8	2
Permanent Marker	8	10	10 / 7	1 / 10	6	1
Pen	10 / 8	1 / 10	10 / 8	4 / 10	R / 8	3 / 10
Crayon	10	10	10	10	10	10
Acrylic Paint	6	10	7 / 6	2 / 10	7 / 6	1 / 10
Oil Paint	6	10	7 / 6	2 / 10	7 / 6	1 / 10
<b>Pressure Washing</b>						
Spray Paint	2	2	1 / 2	1 / 3	-	-
Permanent Marker	2	3	2	8	-	-

Chemical testing procedures consisted of graffiti removal using various solvents on steel and concrete specimens. Based on the results in Table 5, several conclusions can be made regarding chemical test specimens. First, the MC-500 coating had the best graffiti resistant qualities when applied to concrete surfaces, but exhibited poorer performance on steel surfaces. This may be due to the concrete surface appearing very dark when the MC-500 was applied making some graffiti markings difficult to see. Second, the MC-300 had great graffiti resistant qualities on concrete surfaces, but would need to be reapplied after each cycle to be beneficial. Third, the MC-300 had the best overall graffiti resistance on steel surfaces, but would also need to be reapplied after each cycle to be recleanable. Lastly, although MC-300 had the best overall performance on steel surfaces, uncoated steel had very similar results. Furthermore, chemical tests indicated that MC-500 coating performed best on concrete, steel had the best graffiti resistant qualities either uncoated or with the MC-300 coating, and MC-300 should be reapplied between each cycle to be effective.

Pressure washer test procedures consisted of graffiti removal using pressure washing methods on steel and concrete specimens. Based on the results in Table 5, the following conclusions can be made: First, MC-300 coatings displayed the best graffiti resistant qualities when applied to both steel and concrete surfaces. Second, MC-300 should be reapplied after each cycle to ensure recleanability. Next, multiple cycles of pressure washing concrete damaged the coatings and the surface of the concrete. Last, MC-500 was better at preserving the quality of the concrete surface, but did not show graffiti resistant qualities.



## CONCLUSIONS

This report researched and analyzed the graffiti resistance of MicroCor-300 and MicroCro-500 coatings on steel and concrete substrates. The coatings were evaluated for time of set (ASTM D1640) and chemical resistance (ASTM D1308). Additionally, the coatings were tested in accordance with ASTM D6578 Graffiti Removal Using Chemical Testing and ASTM D7089 Graffiti Removal Using Pressure Washing.

The following conclusions can be drawn from this report:

1. Out of the two coatings tested, MicroCor-300 had the better overall graffiti resistant qualities on both steel and concrete surfaces as demonstrated by chemical and pressure washer testing.
2. MicroCor-300 should be reapplied after each cleaning cycle to fully restore graffiti resistant qualities regardless of chosen cleaning method.
3. MicroCor-500 was more durable than MicroCor-300.
4. MicroCor-500 performed best when applied to concrete for chemical testing.

## REFERENCES

ASTM D1308. 2013. "Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes," (ASTM D1308/D1308-02R13), ASTM International, West Conshohocken PA.

ASTM D1640. 2014. "Standard Test Methods for Drying, Curing, or Film Formation of Organic Coatings," (ASTM D1640/D1640M-14), ASTM International, West Conshohocken PA.

ASTM D6578. 2013. "Standard Practice for Determination of Graffiti Resistance," (ASTM D6578/D6578M-13), ASTM International, West Conshohocken PA.

ASTM D7089. 2014. "Standard Practice for Determination of the Effectiveness of Anti-Graffiti Coating for Use on Concrete, Masonry and Natural Stone Surfaces by Pressure Washing," (ASTM D7089-06R14), ASTM International, West Conshohocken PA.

Kansas Department of Transportation (2015). "Anti-Graffiti Coating," Standard Specifications for State Road and Bridge Construction, Topeka, KS.

MicroCor Technologies, Inc. (2015). *MicroCor Technologies, Inc.*, <http://www.microcortech.com/index.html>. Retrieved from MicroCor Technologies, Inc.

Oxford English Dictionary. (2015). (US English). Oxford University Press. Retrieved from Oxford Dictionaries: [www.oxforddictionaries.com](http://www.oxforddictionaries.com)

Weisel, D. L. (2006). *Graffiti*. Washington, D.C.: U.S. Department of Justice, Office of Community Oriented Policing Services.

## **APPENDIX A: Comparison of Results to KDOT Specifications**

### **Specifications**

KDOT has developed special provisions and requirements for anti-graffiti coatings in the Standard Specifications for State Road and Bridge Construction under Section 1729 – Anti-Graffiti Coatings (Appendix A). In general, the specification requires that anti-graffiti coatings (1) do not react deleteriously with the surface, (2) produce a uniform film on the surface free of defects, (3) VOC contents remain in compliance with current national rules for industrial maintenance coatings, and (4) must cure clear or translucent.

Specifically, chemical test coatings, referred to as Type II coatings, must be chemical resistant and cannot be altered or damaged by use of solvents or chemical graffiti removers. In addition, based on ASTM D6578, KDOT specified that graffiti resistance must be cleanability level 8, 9, or 10 with a recleanability of 10 cycles minimum. For pressure washer tests, referred to as Type III tests, coatings are required to allow graffiti removal via high-pressure cold water wash and must be self-recoatable through the life of the coating. Based on ASTM D7089, KDOT specified that graffiti resistance must be Cleanability Level 1 with a recleanability of 10 cycles minimum. Furthermore, both Type II and Type III coatings are required to comply with ASTM D1640 obtaining a set-to-touch time of less than 4 hours, and dry-through time of less than 24 hours. Tables A1 and A2 show the required KDOT specifications for Type II and Type III tests, respectively.

**Table A1: Requirements for Type II Coatings**

<b>Property</b>	<b>Test Method</b>	<b>Requirement</b>
Graffiti Resistance	ASTM D 6578	Cleanability Level 8, 9, or 10
Recleanability	ASTM D 6578	Min. 10 Cycles
Fluid Resistance	ASTM D 1308	No blistering, discoloration, softening or adhesion loss
Set-to-Touch Time	ASTM D 1640	4 hr. maximum
Dry-Through Time	ASTM D 1640	24 hr. maximum

**Table A2: Requirements for Type III Coatings**

<b>Property</b>	<b>Test Method</b>	<b>Requirement</b>
Graffiti Resistance	ASTM D 7089	Cleanability Level 1
Recleanability	ASTM D 7089	Min. 10 Cycles
Set-to-Touch Time	ASTM D 1640	4 hr. maximum
Dry-Through Time	ASTM D 1640	24 hr. maximum

**Time to Set (ASTM D1640):**

Set-to-touch time and dry-through time were evaluated on MC-300 and MC-500 coated Type II and Type III specimens. Both MC-300 and MC-500 coatings met KDOT Specifications for time-of-set requiring set-to-touch time and dry-through time of a maximum of 4 hours and 24 hours, respectively. MC-300 exhibited a set-to-touch time of 15 minutes and a dry-through time of 1.5 hours. MC-500 exhibited a set-to-touch time of 3 hours and a dry-through time of 15 hours.

**Chemical Resistance (ASTM D1308):**

Chemical Resistance testing was performed on Type II steel and concrete specimens coated with MC-300 and MC-500. Although the MC-300 coating did not meet KDOT Specifications, the MC-500 coating met KDOT requirements. When exposed to paint thinner and

gasoline, MC-300 experienced adhesion loss on both steel and concrete surfaces, whereas MC-500 did not exhibit any alterations.

### **Type II Testing – Graffiti Removal Using Solvents (ASTM D6578)**

Type II test procedures involved using various solvents to remove graffiti from steel and concrete surfaces. Even though neither MC-300 nor MC-500 coatings met KDOT Specifications requiring all graffiti types to be a Cleanability Level of 8, 9, or 10 for all 10 cycles, there were a few types of graffiti markings on the various test specimens that met these requirements. The following conclusions were made via results presented in Table 5:

Uncoated concrete specimens resulted in pen and crayon being the only types of graffiti to satisfy KDOT Type II Graffiti Removal Specifications. On MC-300 coated concrete surfaces, pen and crayon met KDOT standards. On MC-500 coated concrete surfaces, water-based marker, pen, and crayon fulfilled KDOT requirements.

For uncoated steel specimens, water-based marker, permanent marker, pen, and crayon all met KDOT criteria. On MC-300 coated steel surfaces, water-based marker, pen, and crayon satisfied KDOT requirements. On MC-500 coated steel surfaces, pen and crayon were the only graffiti types that met KDOT Specifications.

### **Type III Testing – Graffiti Removal Using Pressure Washer (ASTM D7089)**

Type III test procedures required pressure washing methods to remove graffiti from steel and concrete specimens. KDOT Specifications for Type III tests required both types of graffiti to be rated as Cleanability Level 1 for all 10 cycles. Based on Table 5, neither the MC-300 nor MC-500 coatings met the specifications. Cleanability Level 1 was only observed for the following occasions:

MC-300 coated concrete specimens achieved Cleanability Level 1 of both spray paint and permanent marker for two cycles. MC-300 coated steel specimens attained Cleanability Level 1 of spray paint for one cycle.