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Product Material Investigation and Evaluation of Jay's Majic Mud for Use in KDOT Construction and Maintenance Applications

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16 **Abstract**

Jay's Majic Mud (JMM) was investigated for possible use as either a rapid-set patching material or as a potential new alternative, novel, thin-bonded overlay system. In its current pre-packaged form, JMM does not meet the requirements for rapid-set material use, nor does it meet the permeability requirements needed for use as a standalone (neat) mix. JMM performs well as a resurfacing material for light industrial and residential applications, and the novel placement method Jay has developed by use of power troweling each layer works well for these applications. However, this material in its current mix design form does not meet the requirements for use by KDOT in bridge deck patching, pavement patching, or as a thin-bonded bridge overlay system.

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Abstract

Jay's Majic Mud (JMM) was investigated for possible use as either a rapid-set patching material or as a potential new alternative, novel, thin-bonded overlay system. In its current pre-packaged form, JMM does not meet the requirements for rapid-set material use, nor does it meet the permeability requirements needed for use as a standalone (neat) mix. JMM performs well as a resurfacing material for light industrial and residential applications, and the novel placement method Jay has developed by use of power troweling each layer works well for these applications. However, this material in its current mix design form does not meet the requirements for use by KDOT in bridge deck patching, pavement patching, or as a thin-bonded bridge overlay system.

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Chapter 1: Introduction

1.1 Background

KDOT currently uses a variety of thin bonded overlay systems to prolong the life of bridge decks in Kansas. These vary in both thickness and material type from thin ¼-in. bonded polymer overlays to common 1.5-in. silica fume concrete overlays. Jay's Majic Mud was submitted as a potential new material product that could serve as a cost-effective alternative to our conventional materials, offering KDOT benefits both in its ease of use by light contracting or maintenance forces, as well as potential improved product performance.

1.2 Objectives

The main objective of this research was to evaluate the potential use of Jay's Majic Mud (JMM) as a material for thin bonded overlays or as a patching material for use in KDOT construction and maintenance applications. The study was conducted in several phases over the course of two years:

- Phase 1 – Preliminary Investigation & Testing
- Phase 2 – Investigation of In-Service Projects and Field Trial Placement
- Phase 3 – Investigation of Permeability-Enhancing Techniques

Phase 1 (Chapter 2) focused on the preliminary testing of JMM. In the first part of this phase, KDOT prequalification testing for cement was conducted on small-scale JMM mixtures to evaluate if it would meet the KDOT prequalification criteria for a rapid-set cement and/or a blended cement (Type IP). Length change testing was also conducted to determine if it has desirable shrinkage performance. The second part of Phase I focused on the hardened properties of larger scale JMM mixtures. This included testing for compressive strength, permeability performance, and freeze-thaw durability.

Phase 2 (Chapter 3) focused on investigating the performance of in-service JMM projects located in northwestern Kansas. These in-service projects consisted of different types of JMM applications, such as parking lots, sidewalks, staircases, building façade, and a county bridge prototype overlay placement. The projects varied in age and size. An experimental field trial placement of JMM was also done in this phase to assess the techniques used to best mix and place the material in the field.

Phase 3 (Chapter 4) focused on investigating techniques to improve the permeability performance of JMM. In this phase, a permeability-enhancing admixture was added to different JMM mixtures to determine whether or not the permeability of JMM could be improved.

Overall conclusions of Jay's Majic Mud performance and recommendations to improve the material's performance are presented in Chapter 5. The results of additional testing conducted, and the status of future testing are included in Chapter 6.

Chapter 2: Phase I – Preliminary Investigation and Testing

2.1 Rapid-Set Performance of Mortar

Previous applications of Jay's Majic Mud (JMM) in the field have included parking lots, sidewalks, staircase overlays, and a county bridge overlay. The inventor of Jay's Majic Mud has been able to do these types of jobs in as little as a few hours and was interested to see if the material was able to meet the criteria of a rapid-set material. This phase of the research investigates the rapid hardening performance of JMM per Section 2009, Special provision 15-20003 of the 2015 Edition of KDOT's Standard Specification (KDOT, 2018). The following sections summarize the results of the study.

2.1.1 Materials and Mixture Information

Small-scale laboratory mixtures were made with Jay's Majic Mud (JMM) pre-packaged material at the KDOT Materials and Research Center in Topeka, Kansas. Five different mixture designs were investigated and are shown in Table 2.1. The mixtures were designed at different water-to-cementitious materials ratios (w/cm); however, the w/cm recommended by the producer is 0.16 to achieve the optimal flow properties for typical JMM applications. Two of the mixtures were normal JMM mixtures, meaning they did not contain any additives. In three other mixtures, a non-chloride accelerator was pre-blended with JMM at different dosages to evaluate the material's ability to set rapidly. The JMM mixture with w/cm = 0.16 was used as a control mixture to compare the results of the other JMM mixtures.

Table 2.1: General Mix Information for Rapid Hardening Performance

Mixture ID	Description	W/cm	Additives
w/cm = 0.16	JMM pre-packaged material	0.16	None
w/cm = 0.14	JMM pre-packaged material	0.14*	None
+ 3 lbs Accel.	JMM + non-chloride accelerator	0.11*	3 lbs of accelerator per 50 lbs of JMM
+ 4 lbs Accel.	JMM + non-chloride accelerator	0.11*	4 lbs of accelerator per 50 lbs of JMM
+ 5 lbs Accel.	JMM + non-chloride accelerator	0.11*	5 lbs of accelerator per 50 lbs of JMM

*Optimized for normal consistency flow per ASTM C109; not the producer recommended w/cm ratio.

2.1.2 Sample Preparation, Conditioning, and Testing

After preparing each JMM mixture, samples were prepared for cement compressive strength testing (ASTM C109, 2020) at different time intervals. Three 2-in. cube specimens were made for each testing day. On each test day, the maximum peak load was recorded for each cube and used to calculate the compressive strength.

2.1.3 Results and Discussion

In Figure 2.1, the compressive strength data for all five JMM mixtures is presented. The results of the compressive strength testing for each mixture were compared to the minimum compressive strength requirements for rapid hardening at different ages according to ASTM C1600 (2020). These requirements are presented below in Table 2.2, as well as shown on the graph in Figure 2.1.

Table 2.3 presents the comparison between the compressive strength values of the JMM mixture with w/cm = 0.16 (producer-recommended w/cm) and the other four mixtures. This comparison was done to show the effects that w/cm and the addition of an accelerator had on the compressive strength performance of JMM.

Table 2.2: Minimum Strength Requirements for Rapid Hardening (ASTM C1600)

	Classification of Hardening			
	GRH (General Rapid)	MRH (Medium Rapid)	VRH (Very Rapid)	URH (Ultra Rapid)
Uses / Time of Test	Higher strength properties of VRH or MRH not required	Mid-range hardening high early strength desired	Very high early strength desired	Ultra-high early strength desired
3 hours	1000 psi	1500 psi	2200 psi	4100 psi
1 day	2000 psi	2500 psi	3500 psi	5100 psi
7 days	3500 psi	4100 psi	4100 psi	6000 psi

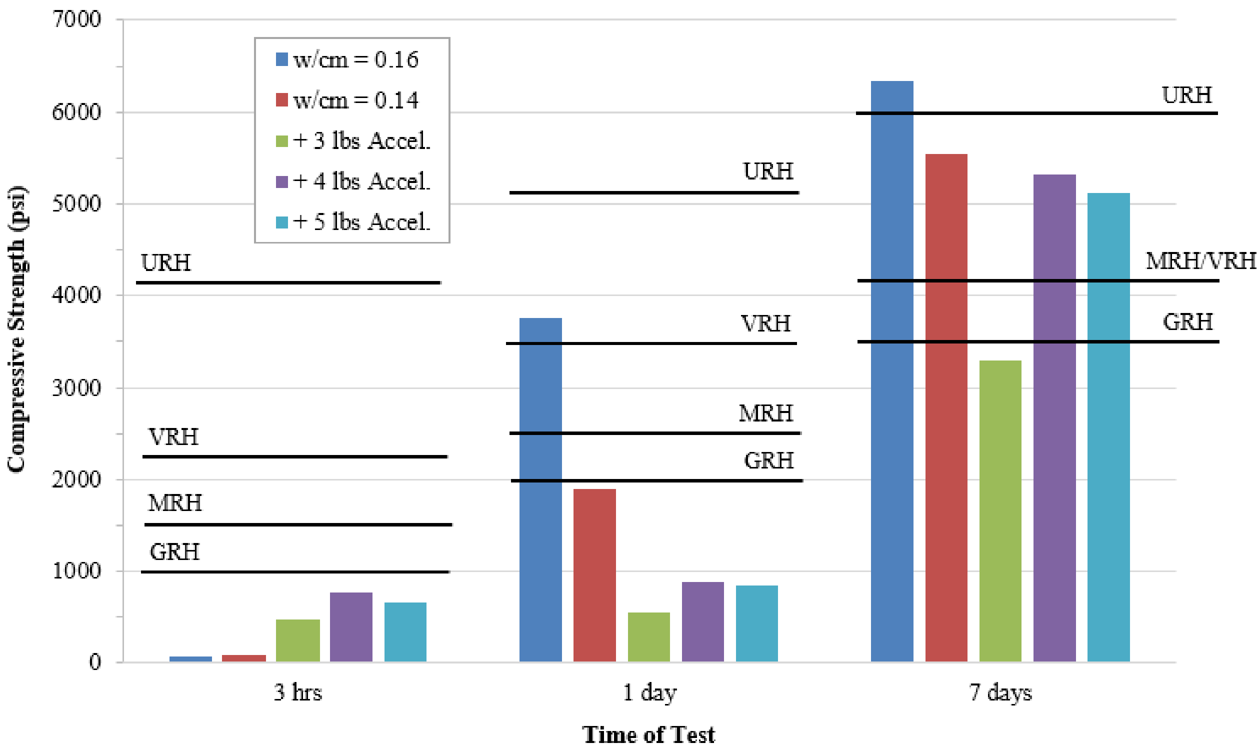


Figure 2.1: Compressive Strength (ASTM C109) Results for JMM Mixtures

According to Figure 2.1, the JMM mixture with w/cm = 0.16 shows the lowest compressive strength value at 3 hours, but the highest compressive strength value at 7 days, and would have met Ultra Rapid Hardening (URH) classification. The mixtures with accelerator added had the highest compressive strengths at 3 hours but were quickly surpassed by the normal JMM mixtures at 1 day. By 7 days, the mixtures with 4 lbs and 5 lbs of accelerator were able to meet Medium/Very Rapid Hardening (MRH/VRH) classification; however, the mixture with 3 lbs accelerator never reached General Rapid Hardening (GRH) classification. At this stage in the analysis, it is unknown why this occurred, and further work would need to be undertaken by running calorimetry on each mix variant to determine what effect the accelerator is having on hydration and water demand.

Table 2.3: Compressive Strength Change Compared to W/Cm = 0.16 Mixture

Time of Test	w/cm = 0.14	+ 3 lbs Accel.	+ 4 lbs Accel.	+ 5 lbs Accel.
3 hours	16%	145%	165%	159%
1 day	-66%	-149%	-124%	-126%
7 days	-13%	-63%	-18%	-22%

[1]Percent difference = $\frac{|V1-V2|}{\left(\frac{V1+V2}{2}\right)} \times 100$; V_1 = value 1, V_2 = value 2

The results in Table 2.3 show that JMM mixture with w/cm = 0.14 had significantly lower compressive strength at 1 day (66% lower) compared to the JMM mixture that was prepared at the producer-recommended w/cm ratio (w/cm = 0.16). However, by 7 days, the 0.14 w/cm mixture was able to achieve a compressive strength that was less than 20% lower than the 0.16 w/cm mixture.

Since none of the five JMM mixtures investigated in this study were able to consistently meet any of the hardening classification requirements at every test time, JMM cannot not be prequalified by KDOT as a Rapid Hardening cement per the Standard Specifications in its current form.

2.1.4 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- None of the mixtures met the full criteria for any ASTM C1600 Rapid Hardening classification. Some mixtures met some of the classifications, but all must be met to pass as a rapid-set cement.
- Adding a non-chloride accelerator did not improve the rapid-set performance of JMM when compared to mixtures without an accelerator.

2.2 Length Change Performance of Mortar

This section is a continuation of the previous section (2.1) and investigates the length change performance of Jay's Majic Mud (JMM). The results were compared to the length change performance requirements from ASTM C1600 (2020) "Standard Specification for Rapid

Hardening Hydraulic Cement" to determine whether JMM meets the requirements or not. This ASTM standard is also what is referenced for prequalification of Rapid Hardening cement per Section 2009, Special Provision 15-20003 to KDOT's Standard Specifications (2015 Edition). The following sections summarize the results of the study.

2.2.1 Materials and Mixture Information

Laboratory mixtures were made with Jay's Majic Mud (JMM) pre-packaged material at the KDOT Materials and Research Center in Topeka, Kansas. One mixture design was investigated as shown in Table 2.4. The mixture was designed to have a w/cm = 0.16, which is the w/cm recommended by the producer to achieve the optimal flow properties for typical JMM applications.

Table 2.4: General Mix Information for Length Change Performance

Mixture ID	Description	W/cm	Additives
w/cm = 0.16	JMM pre-packaged material	0.16	None

2.2.2 Sample Preparation, Conditioning, and Testing

After preparing the JMM mixture, three 1 x 1 x 11.25 in. bar samples were prepared for length change testing per ASTM C157 (2017). The samples were cast in molds and demolded after 24 ± 2 hours. After demolding, the samples were placed in an environmentally controlled room kept at a temperature of 73 ± 3 °F and 100% relative humidity for 7 days. Initial length measurements were taken on each sample at 7 days and then the samples were stored in air in an environmental cabinet kept at a temperature of 73 ± 3 °F and 50% relative humidity for 28 days. After being stored in air for 28 days (35 total days of conditioning), final length measurements were taken on each sample.

These measurements were used to compute the average length change of the JMM mixture. The results of the length change testing were compared to the maximum increase in length change allowed by the specification requirements for cement prequalification per ASTM Standard C1600 (2020).

2.2.3 Results and Discussion

The following table presents the length change results for the JMM mixture.

Table 2.5: Length Change Results of JMM Mixture and ASTM C1600 Requirements

JMM Results		Classification of Hardening			
Time of Test	Length Change (%)	GRH (General Rapid)	MRH (Medium Rapid)	VRH (Very Rapid)	URH (Ultra Rapid)
28 days, air storage	0.114%	0.12%	0.09%	0.07%	0.07%

According to the results presented in Table 2.5, the JMM mixture met the requirements for GRH (General Rapid Hardening) classification. However, since none of the compressive strength requirements were met for any of the hardening classifications (w/cm = 0.16 mixture from Section 2.1.3), JMM cannot be prequalified by KDOT as a rapid hardening cement.

2.2.4 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- When mixed at the producer-recommended w/cm ratio (w/cm = 0.16), JMM meets the length change requirements for GRH (General Rapid Hardening) classification. However, the mixture was not able to meet the compressive strength requirements for GRH at 3 hours, 1 day, and 7 days.
- JMM cannot be prequalified by KDOT as a rapid hardening cement per the Standard Specifications (KDOT, 2015).

2.3 Prequalification Testing for Blended Cement

KDOT prequalification testing was conducted on Jay's Majic Mud (JMM) to determine if it would meet the physical property requirements for a blended cement (Type IP). If it meets all the requirements, then JMM could be prequalified by KDOT to be used as a blended cement and it could be used on KDOT construction projects. This phase of the research investigates whether

JMM could be prequalified by KDOT as a blended cement, and the following sections summarize the results of the study.

2.3.1 Sample Preparation, Conditioning, and Testing

The following testing was conducted on small-scale JMM mixtures. All sample preparation, conditioning, and testing procedures were followed per each test's standard.

- Setting time (ASTM C191, 2021)
- Autoclave Expansion (ASTM C151, 2018)
- Air Content (ASTM C185, 2020)
- Density (ASTM C188, 2017)
- Blaine Fineness (ASTM C204, 2019)
- Percent Retained on No. 325 Sieve (ASTM C430, 2017)
- Compressive Strength (ASTM C109, 2020)

2.3.2 Results and Discussion

The following tables show JMM's physical test results for KDOT prequalification for blended cement (IP) which were mixed at a w/cm ratio of 0.14 to achieve a flow of 108 in keeping with C109 requirements for a Type IP.

Table 2.6: Overview of Physical Test Results

Type	Setting Time (min) (C191)		Autoclave Expansion (%)	Air Content (%)	Density (gm/cm^2)	Blaine Fineness (m^2/kg)	% Retained on 325
	Initial	Final	(C151)	(C185)	(C188)	(C204)	(C430)
Type IP Req.	>45	<7 hrs	-0.20 min / +0.80 max	12 max.	N/A	260-430	N/A
JMM Results	**61**	**120**	**0.044**	**14.3**	**2.75**	**117**	**50.84**
Pass/Fail	Pass	Pass	Pass	Fail	--	Fail	--

Table 2.7: Overview of Compressive Strength Results (ASTM C109)

Type	3 Day Strength (psi)	7 Day Strength (psi)	28 Day Strength (psi)
Type IP Req.	1890	2900	3620
JMM Results	**470**	**670**	**810**
Pass/Fail	Fail	Fail	Fail

According to the results in Table 2.6, JMM exceeds the requirements for air content. Also, it did not meet the requirement for Blaine fineness. The requirements for a blended cement are 260 to 430 m^2/kg, and the measured fineness of JMM was 117 m^2/kg, which means the JMM is not a fine enough material.

The results in Table 2.7 show that JMM does not meet the compressive strength requirements of a prequalified blended cement at any day of interest (3, 7, and 28 days).

2.3.3 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- JMM does not meet the blended cement requirements for air content, Blaine fineness, and compressive strength.
- Since at least one prequalification criteria was not met, JMM cannot be prequalified by KDOT as a blended cement (Type IP) per Standard Specifications.

2.4 Strength and Permeability Performance of Concrete

This phase of the research consisted of investigating the compressive strength and permeability performance of Jay's Majic Mud concrete mixtures. To be used as an overlay material, JMM must meet the permeability performance requirements outlined in Section 402-1 of the KDOT (2015) Standard Specifications. If it does not meet these requirements, it cannot be prequalified for use on KDOT projects.

2.4.1 Materials and Mixture Information

Laboratory mixtures were made with Jay's Majic Mud (JMM) pre-packaged material at the KDOT Materials and Research Center in Topeka, Kansas. Three mixture designs were investigated and are shown in Table 2.8. One mixture was designed to have a w/cm = 0.16, which is the w/cm recommended by the producer to achieve the optimal flow properties for typical JMM applications. The second mixture was designed to have a w/cm = 0.23 to evaluate JMM's performance if mixed at a much higher w/cm ratio. The third mixture was the same design as the first mixture (w/cm = 0.16), but a pre-saturated lightweight aggregate (LWA) was added to the JMM mixture at a 20% replacement by volume. The JMM mixture with w/cm = 0.16 was used as a control mixture to compare the results of the other JMM mixtures.

Table 2.8: General Mix Information for Concrete Strength and Permeability Performance

Mixture ID	Description	W/cm	Additives
w/cm = 0.16	JMM pre-packaged material	0.16	None
w/cm = 0.23	JMM pre-packaged material	0.23*	None
+ LWA (w/cm = 0.16)	JMM + LWA	0.16	Includes 20% pre-saturated LWA (1/2" x #4)

*Not the producer recommended w/cm ratio.

2.4.2 Sample Preparation, Conditioning, and Testing

After preparing the mixtures, samples were prepared for compressive strength (ASTM Standard C39, 2021; KT-76 Kansas Test Method, 2018), surface resistivity (SRM) (KT-79 Kansas Test Method, 2018), volume of permeable voids (KT-73 Kansas Test Method, 2018), and rapid chloride permeability (RCP) (AASHTO Standard T277, 2011). The number of samples with the test method can be summarized in Table 2.9 and additional information about sample preparation and testing can be found in the following subsections.

Table 2.9: JMM Concrete Testing Information

Test Property	Test Method	Sample Size	Sample Count
Compressive Strength	KT-76	4 x 8 in. cylinder	3 per test (Variable test dates)
Surface Resistivity (SRM)	KT-79	4 x 8 in. cylinder	3 per test (28 and 56 d)
Volume of Permeable Voids (Boil Test)	KT-73	2 in. puck (Cut from 4 x 8 in. cylinder)	3 (28 d)
Rapid Chloride Permeability (RCP)	AASHTO T277	2 in. puck (Cut from 4 x 8 in. cylinder)	3 (56 d)

From each mixture, 4 x 8 in. concrete cylinders were made and cured according to KT-22 Kansas Test Method (2018) for compressive strength testing. Three cylinders were made for each testing day. The cylinders were kept in their molds for the first 24 ± 2 hours and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were capped (per KT-77 Kansas Test Method, 2018), measured, and tested for compressive strength (per KT-76 Kansas Test Method, 2018). The maximum peak load and stress were recorded for each cylinder.

Three 4 x 8 in. concrete cylinders were made and cured according to KT-22 Kansas Test Method (2018) for volume of permeable voids testing (KT-73 Kansas Test Method, 2018). The cylinders were kept in their molds for the first 24 ± 2 hours and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were cut down to 2-in.-thick pucks and tested as per KT-73 Kansas Test Method (2018). Prior to being cut and tested, the 28-day SRM of all three cylinders was measured per KT-79 Kansas Test Method (2018). Eight readings were taken on each cylinder and were averaged to report a single resistivity value.

Three 4 x 8 in. concrete cylinders were made and cured according to KT-22 Kansas Test Method (2018) for rapid chloride permeability testing (AASHTO Standard T277, 2011). The cylinders were kept in their molds for the first 24 ± 2 hours and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were cut down to 2-in.-thick pucks and tested as per

AASHTO T277. Prior to being cut and tested, the 56-day SRM of all three cylinders was measured per KT-79 Kansas Test Method (2018). Eight readings were taken on each cylinder and were averaged to report a single resistivity value.

2.4.3 Results and Discussion

The following subsections present the compressive strength and permeability results of the JMM mixtures.

2.4.3.1 Compressive Strength Results

The compressive strength results of two JMM mixtures are presented below in Figure 2.2. No compressive strength testing was conducted on the mixture with LWA added due to a shortage in material.

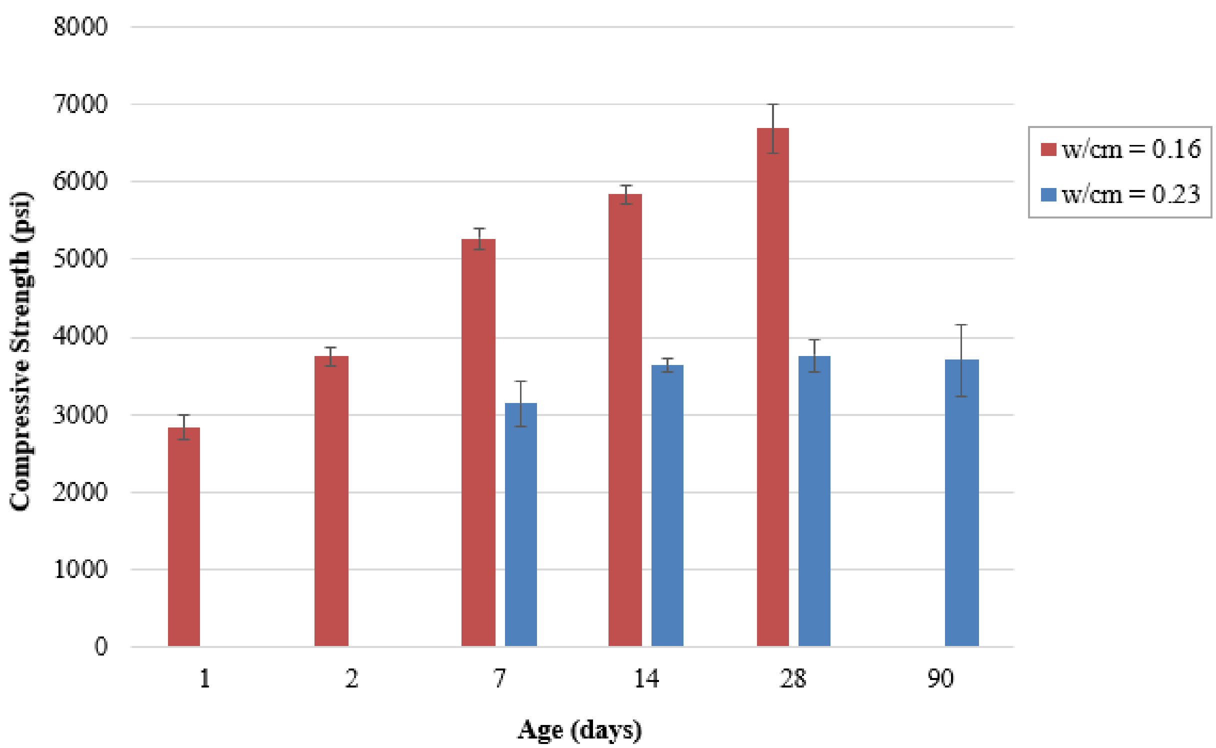


Figure 2.2: Compressive Strength (KT-76) Results (No Results for + LWA Mixture)

According to Figure 2.2, the 0.16 w/cm mixture was able to achieve a compressive strength of 6,700 psi at 28 days, while the 0.23 w/cm mixture reached 3,760 psi (a 44% reduction). These results show the effect that the w/cm ratio has on the compressive strength of concrete mixtures. When mixed at the producer-recommended w/cm, the JMM mixture was able to meet very high compressive strengths. When too much water was added to the JMM, the compressive strength was cut almost in half of what it should be at the correct w/cm ratio.

2.4.3.2 Permeability Results

The surface resistivity, volume of permeable voids, and rapid chloride permeability results of the JMM mixtures are presented below in Figures 2.3, 2.4, and 2.5, respectively. Also presented in Table 2.10 are the KDOT permeability criteria for different concrete applications per Section 402-1 of the Standard Specifications (KDOT, 2015). Table 2.11 summarizes the overall permeability performance of the JMM trial pour according to Section 402-1 (KDOT, 2015). Jay's Majic Mud is a material that is commonly used for overlays, so it must meet Low Permeability classification to be used on KDOT projects.

Table 2.10: KDOT Concrete Permeability Criteria (per Section 402-1)

Permeability Classification	Boil (%)	SRM (kΩ-cm)	RCP (coulombs)	Application (Per section 402-1 of KDOT spec)
Standard	12 (max)	9 (min)	3,000 (max)	All structural concrete not specified as Low or Moderate perm.
Moderate	11 (max)	13 (min)	2,000 (max)	Full depth bridge decks
Low	9.5 (max)	27 (min)	1,000 (max)	Bridge overlays

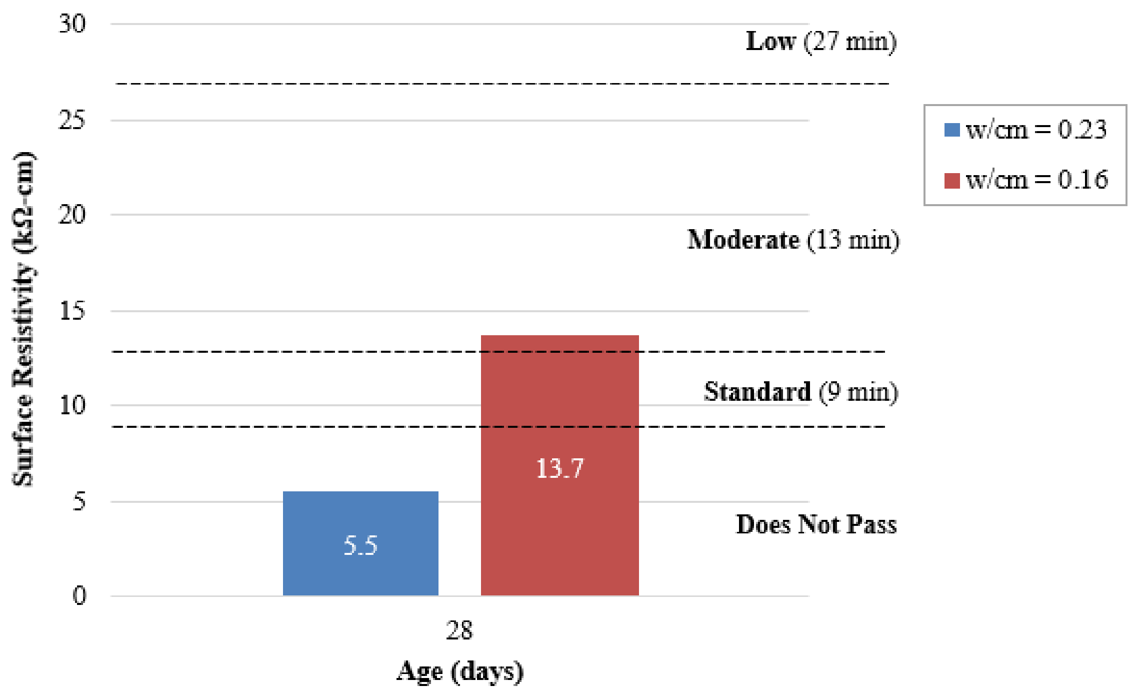


Figure 2.3: Surface Resistivity (KT-79) Results (No Results for + LWA Mixture)

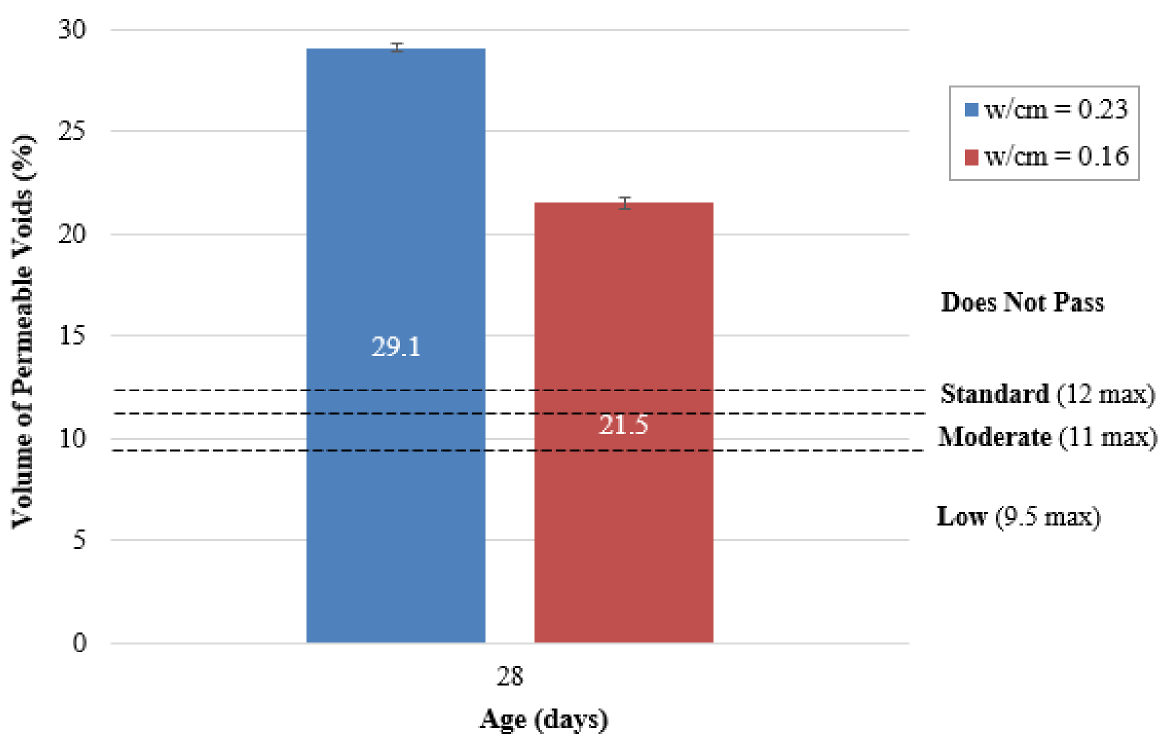


Figure 2.4: Volume of Permeable Voids (KT-73) Results (No Results for + LWA Mixture)

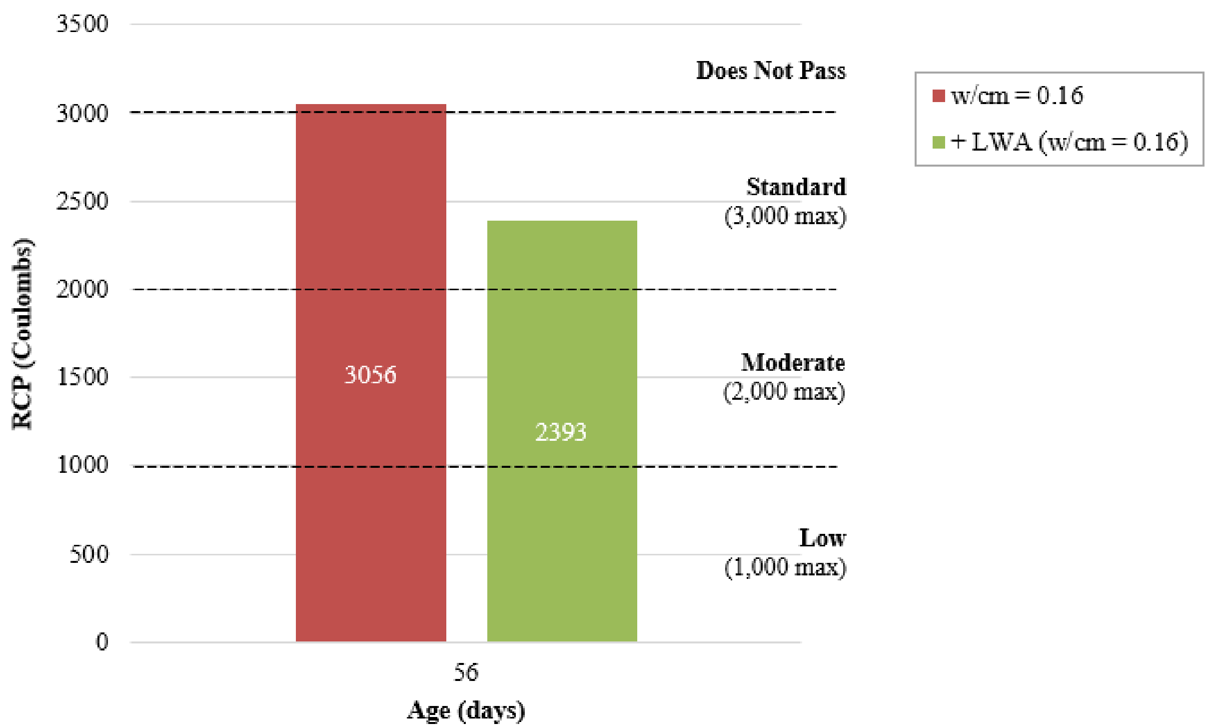


Figure 2.5: Rapid Chloride Permeability (AASHTO T-277) Results (No Results for 0.23 w/cm Mixture)

Table 2.11: Summary of Permeability Performance According to Section 402-1

Mixture ID	KT-79: 28-d SRM	KT-73: 28-d Vol. of Perm. Voids	AASHTO T-277: 56-d RCP
w/cm = 0.16	Moderate	Does not pass	Does not pass
w/cm = 0.23	Does not Pass	Does not pass	--*
+ LWA (w/cm = 0.16)	--*	--*	Standard

*Did not test.

According to Figures 2.3, 2.4, and 2.5, and Table 2.11, none of the JMM mixtures meet the KDOT requirements for Low Permeability, which is necessary to be used as an overlay material for KDOT projects. The addition of LWA seemed to improve the 56-day RCP performance when compared to the 0.16 w/cm mixture, but it still did not meet the Low Permeability criteria.

2.4.4 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- The w/cm ratio is incredibly important when batching this product. When mixed at the proper w/cm = 0.16, JMM was able to reach nearly 7,000 psi at 28 days. Most construction or maintenance applications only need 4,500 psi. However, when mixed at a w/cm = 0.23, the 28-day compressive strength was reduced to 3,700 psi. This shows the importance of batching the material at the correct w/cm to achieve expected compressive strength performance.
- JMM was not able to achieve KDOT's Low Permeability requirements, which is required to be used as a bridge deck overlay material.

2.5 Freeze-Thaw Performance of Concrete

This section summarizes the results of an investigation into the freeze-thaw performance of Jay's Majic Mud, as well as a hardened air analysis.

2.5.1 Materials and Mixture Information

Laboratory mixtures were made with Jay's Majic Mud (JMM) pre-packaged material at the KDOT Materials and Research Center in Topeka, Kansas. Two mixture designs were investigated and are shown in Table 2.12. One mixture was designed to have a w/cm = 0.16, which is the w/cm recommended by the producer to achieve the optimal flow properties for typical JMM applications. The second mixture was the same design as the first mixture (w/cm = 0.16), but a pre-saturated lightweight aggregate (LWA) was added to the JMM mixture at a 20% replacement by volume. The JMM mixture with w/cm = 0.16 was used as a control mixture to compare the results of the other JMM mixture.

Table 2.12: General Mix Information for Freeze-Thaw Performance

Mixture ID	Description	W/cm	Additives
w/cm = 0.16	JMM pre-packaged material	0.16	None
+ LWA (w/cm = 0.16)	JMM + lightweight aggregate (LWA)	0.16	Includes 20% pre-saturated LWA (1/2” x #4)

2.5.2 Sample Preparation, Conditioning, and Testing

After preparing the mixtures, samples were prepared for freeze-thaw testing according to KTMR-22 (2012) “Resistance of Concrete to Rapid Freezing and Thawing.” This is a Kansas test method that is only run at the Materials and Research Laboratory in Topeka, Kansas. It follows the procedures set forth in ASTM C666 (2016), “Test Method Resistance of Concrete to Rapid Freezing and Thawing” (Procedure B), with the following exceptions:

The test specimens were cured for 90 days. The curing timeline is as follows:

- After molding, specimens were cured in an ASTM C511 (2021) “moist room” until they reached 67 days of age.
- Specimens were transferred to an ASTM C511 (2021) “cement mixing room” until they reached an age of 88 days.
- Specimens were submerged in tap water maintained between 60 °F and 80 °F for 24 hours.
- Specimens were submerged in tap water maintained at 40 °F for 24 hours.

After 90 days of curing, the specimens were subjected to rapid freezing and thawing. Every 56 cycles, the length change (ASTM C157, 2017), weight change, and resonant frequency (ASTM C215, 2020) were recorded for each specimen. The testing continued until each specimen was subjected to at least 660 cycles, it’s relative dynamic modulus reached 60% of the initial modulus, or its expansion reached or exceeded 0.10%, whichever occurred first (KTMR-22 Kansas Test Method, 2012).

Three 3 x 4 x 16 in. beam specimens were prepared for freeze-thaw testing for each JMM mixture. One set of specimens (w/cm = 0.16 mixture) contained a shallow saw cut down the middle of the longitudinal axis of each beam’s 4-in.-wide face. This was done to mimic a saw-cut joint and expose the internal aggregate/paste structure to accelerated moisture ingress.

A hardened air analysis was also run according to ASTM C457 (2017) "Determination of Parameters of the Air-Void System in Hardened Concrete" on the samples to measure the hardened air volume and the spacing factor of the JMM mixtures.

2.5.3 Results and Discussion

The results for this section are provided based on freeze-thaw testing (KTMR-22 Kansas Test Method, 2012; ASTM C666, 2016) and hardened air analysis (ASTM C457, 2017) in the following sections.

2.5.3.1 Freeze-Thaw Results

In Kansas, aggregate sources are prequalified by KDOT based on freeze-thaw testing with KTMR-22 (McLeod, Welge, & Henthorne, 2014). Therefore, the Kansas test method for freeze-thaw durability is not necessarily a proper performance measurement of the air-void system in the paste. However, since JMM contains only fine aggregate, freeze-thaw testing was conducted purely to compare different JMM mixtures to one another, and to other existing bridge deck mixes that we have previously tested.

KDOT's Specifications for On Grade Concrete Aggregate (OGCA) require aggregate sources to reach a Relative Dynamic Modulus of Elasticity (RDME) ≥ 95% and percent expansion (%E) ≤ 0.025% at 660 cycles of freeze-thaw testing (Section 1116, KDOT, 2015). This is different from ASTM C666 (2016) "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing," which uses the Durability Factor (DF), a calculated value, to define the freeze-thaw durability performance of a concrete mixture – which KDOT does use to qualify rapid-set patching material. (It must have a DF of 90% or greater at 300 cycles. [Section 1716, KDOT, 2015]). This means that the freeze-thaw performance of JMM will be presented in terms of the KDOT OGCA specifications and ASTM C666 criteria in order to see the difference. The results for both JMM mixtures are presented below in Table 2.13.

Table 2.13: Freeze-Thaw Results for JMM Mixtures

Mixture ID	No. of Specimens	Cut or Uncut?	KTMR-22			ASTM C666		
			Cycles @ RDME = 95%	RDME % @ 660 Cycles	Pass or Fail?	RDME % @ 300 Cycles	DF @ 300 Cycles	Pass or Fail?
w/cm = 0.16	3	Cut	64	0	Fail*	0	19	Fail**
w/cm = 0.16	3	Uncut	37	0	Fail*	5	11	Fail**
+ LWA (w/cm = 0.16)	3	Uncut	344	83	Fail*	96	90	Pass

*A "Fail" means that the mixture did not reach 660 freezing and thawing cycles with an RDME value staying above 95%.

** A "Fail" means that the mixture did not have a DF of 90 or above at 300 cycles.

According to Table 2.13, the 0.16 w/cm specimens failed less than 100 freezing and thawing cycles into the test (64 and 37 cycles, respectively), which indicates very poor freeze-thaw performance. KTMR-22 and ASTM C666 require specimens to reach 660 and 300 cycles, respectively, in order to qualify as passing, and neither were met by the 0.16 w/cm mixture. However, it seems as though the addition of LWA to the mixture improved the freeze-thaw performance of the JMM. Although the JMM mixture with LWA added did not meet the passing criteria for KTMR-22, it did meet passing criteria for ASTM C666. LWA is a porous aggregate that contains additional mechanical air voids within the aggregate created during the production process. To create LWA, it is introduced into a rotary kiln, where it is heated to extremely high temperatures. The resulting expanded LWA particles contain numerous microscopic, non-connected air voids, making the product lightweight, strong, and durable. These microscopic air voids then act as additional mechanical air void system in the JMM mixture, which improve the freeze-thaw durability by allowing spaces for water to freeze and expand without damaging the surrounding paste matrix.

The results in Table 2.13 also show that the uncut specimen (w/cm = 0.16 mixture) failed before the cut specimen. This was not expected, since the cut specimen should theoretically allow water to penetrate into the specimen further than the uncut sample, which would accelerate the deterioration of the sample as it freezes and thaws repeatedly. This is likely due to the reduced paste strength resulting from the higher air content in the uncut specimen (16% vs the 12% for the cut specimen).

A table summarizing the freeze-thaw performance of Jay's Majic Mud and seven other research projects is shown in **Appendix A** of this document. This table shows how Jay's Majic Mud compares to these other projects in terms of its freeze-thaw performance.

2.5.3.2 Hardened Air Analysis Results

The hardened air analysis results are shown below in Table 2.14.

Table 2.14: Hardened Air Analysis Results for JMM Mixtures

Mixture ID	No. of Specimens	Cut or Uncut?	Ave. Hardened Air Content (%)	Ave. Spacing Factor (in.)
w/cm = 0.16	2	Cut	11.5	0.015
w/cm = 0.16	2	Uncut	16.0	0.013
+ LWA (w/cm = 0.16)	1	Uncut	12.6	0.014

According to Table 2.14, the hardened air contents ranged from 11.5% to 16% in the JMM mixtures. This is a much higher air content than conventional non air-entrained concrete, which typically contains 1 to 2 percent air volume. The measured air contents are also about twice as high as what KDOT normally specifies for a standard air-entrained concrete, which is 6.5% air content. KDOT Section 401.3a.(5) for General Concrete (KDOT, 2015) also sets a maximum air content of 10% for General Concrete, which JMM does not comply with. High air contents could lead to poor strength and permeability performance; if the air inside the JMM mixtures is interconnected in structure, it will allow water and chemicals to easily flow through it and lead to rapid deterioration.

The spacing factors presented in Table 2.14 range from 0.013 in. to 0.015 in. in the JMM mixtures. This indicates a slightly coarser air void system than is normally desired for air-entrained concrete mixtures. KDOT's Specification limits the spacing factor in concrete paving applications to 0.010 or less, 0.008 being considered the optimum value (Section 403.3e, KDOT, 2015).

2.5.4 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- Adding LWA to JMM improved its freeze-thaw performance enough to pass the durability factor (DF) requirements of ASTM C666.
- The hardened air contents of JMM ranged from 11.5% to 16%, which is higher than the KDOT limit of 10% for air-entrained mixes.
- The spacing factors ranged from 0.013 in. to 0.015 in., which indicates a slightly coarser air void system than is normally desired for air-entrained concrete mixtures. KDOT's Specification limits the spacing factor in concrete paving applications to 0.010 or less, 0.008 being considered the optimum value.

2.6 Phase 1 Conclusions

After completing the Phase 1 testing, the following preliminary conclusions are summarized below:

- Jay's Majic Mud did not achieve the rapid hardening compressive strength requirements to become prequalified as a Rapid Hardening cement according to current KDOT (2018) Standard Specifications (Section 2009, Special provision 15-20003). Adding a non-chloride accelerator to Jay's Majic Mud did not improve its rapid set performance.
- The w/cm ratio is incredibly important when batching this product. When mixed at the proper w/cm = 0.16, JMM was able to reach nearly 7,000 psi at 28 days. However, when mixed at a w/cm = 0.23, the 28-day compressive strength was reduced to 3,700 psi. This shows the importance of batching the material at the correct w/cm to achieve expected compressive strength performance.
- JMM was not able to achieve KDOT's low permeability requirements, which is required to be used as a bridge deck overlay material.

- Adding LWA did improve the freeze-thaw performance of JMM; however, when mixed without LWA, it did not reach 300 cycles required by rapid-set requirements.
- The hardened air results for JMM ranged from 11.5% to 16%. This is a much higher air content than air-entrained concrete specified by KDOT Section 401.3a.(5) for General Concrete (KDOT, 2015), which specifies 6.5% air. Section 401.a also sets a maximum air content of 10% for General Concrete, which JMM exceeds.

Chapter 3: Phase 2 – Investigation of In-Service Performance

3.1 Assessment of Existing Projects in Service

KDOT Research met with the inventor of Jay's Majic Mud (JMM) in Phillipsburg, Kansas, on July 9, 2021, to observe the field performance of several finished projects that have utilized JMM as a concrete material during the construction process. The finished projects span a variety of different construction applications, such as parking lot overlays, sidewalk overlays, staircase overlays, exterior masonry façade on buildings, and even a county bridge overlay. The following subsections summarize the different projects investigated by KDOT Research, including their locations and photos showing their condition.

3.1.1 Summary of Existing JMM Projects

The following table summarizes each of the existing in-service projects that utilized JMM as a construction material.

Table 3.1: Summary of Existing JMM Projects

Project	Location	Description	Age
Phillipsburg Post Office	888 2nd St., Phillipsburg, KS 67661	JMM applied to the top of sidewalks surrounding the building and the parking lot/loading dock area south of the building	1 to 1.5 years
Don's TV Store	724 4th St., Phillipsburg, KS 67661	JMM applied to the top of sidewalk directly in front of the store front	10 to 12 years
City of Phillipsburg Community Building	425 F Street, Phillipsburg, KS 67661	JMM applied to the top of badly weathered stairs in front of the building	10 to 12 years
County Bridge Overlay	E 1100 Rd over Deer Cr. N. of 9 Hwy, Kirwin, KS	JMM applied to the top of the bridge deck (~5,500 ft^2) as a thin bonded overlay in 2015	6 years

3.1.1.1 Phillipsburg Post Office

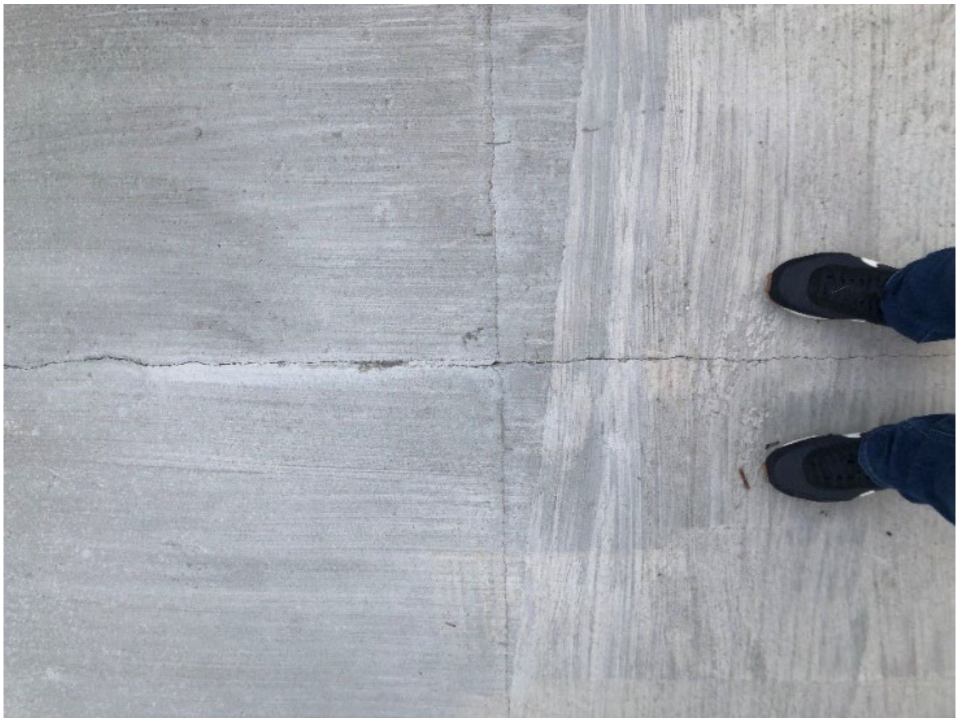


Figure 3.1: Reflective Cracking Over Underlying Joints of Sidewalk

Figure 3.2: Small Isolated Spall Near Reflected Joint on Sidewalk Showing Underlying Thickness of Each Bonded Layer

Figure 3.3: Typical Substrate Prior to Overlay Placement

Figure 3.4: Typical Isolated Surface Dunes Reflected up from Heavily Weathered Substrate


Figure 3.5: Typical Broomed Final Surface Finish of Parking Lot

3.1.1.2 Don's TV Store

Figure 3.6: Map Cracking and Reflective Cracking Over Underlying Joints of Sidewalk

Figure 3.7: Map Cracking, Longitudinal Cracking, and Isolated Spalling Near Joint of Sidewalk

Figure 3.8: Isolated Medium Spall Near Reflected Joint on Sidewalk Showing Underlying Thickness of Each Bonded Layer

3.1.1.3 City of Phillipsburg Community Building

Figure 3.9: Typical Map Cracking with Efflorescence

Figure 3.10: Typical Substrate Condition Prior to Topping

Figure 3.11: Rust Staining Coming Up Through Map Cracks


Figure 3.12: Typical Map Cracking of JMM Overlay

3.1.1.4 County Bridge Overlay

Figure 3.13: Typical Isolated Large Pattern Map Cracking

Figure 3.14: Typical Preliminary Delamination with Map Cracking


Figure 3.15: Typical Preliminary Medium Delamination with Pending Spall


Figure 3.16: Typical Medium Spall

3.1.2 Conclusions

After observing a variety of in-service JMM projects, the following conclusions were made:

- Reflective cracking was noted at joints and seams and is considered normal with this type of thin overlay. Several areas exhibited surface spalling where substrate deterioration might not have been addressed before overlaying. As the thin overlay begins to crack, water will flow through the overlay and in the overlay-substrate interface, which will lead to spalling of the overlay surface. This was noticeable in several of the existing JMM overlays.
- Moderate map cracking (plastic shrinkage cracking) was noted in some locations. Plastic shrinkage cracking appears to be the most common issue for JMM. Further investigation might look at the use of either a small dosage of poly microfibers to increase the tensile capacity of the JMM at the surface or the use of a shrinkage reducing admixture.
- Proper surface preparation is critical, both in the repair of damaged substrate and the production of good surface profile for bond.
- JMM exhibits decent bond when each layer is placed on a well-prepared substrate and when each layer is power-troweled/textured before each successive layer is placed on top of the preceding layer. Poor results were observed when each successive layer is placed using only a roller screed or vibrating screed without the use of the power-trowel consolidation.

3.2 Experimental Field Trial Placement

KDOT Research and other members of the Phillipsburg Area Office met with the inventor of Jay's Majic Mud at B&B Redimix in Phillipsburg, Kansas, on September 1, 2021, to conduct an experimental multi-layer trial placement using Jay's Majic Mud (JMM). An overview of the trial placement is described in the next section, along with pictures describing each step of the process.

3.2.1 Overview of Trial Placement

- Location: south lot of B&B Redimix in Phillipsburg, Kansas
- Size of Trial Placement: 30 ft. x 11 ft.
- Total Overlay Thickness: 0.5 in. (3 layers total)

Table 3.2: Overview of Trial Placement

Layer	Description	W/cm	Paste Content (%)	Thickness (in.)	Placement Start Time	Placement End Time
1	JMM pre-packaged material	0.16	84	0.125	7: 30 am	7:52 am
2 – LWA*	JMM + LWA	0.14**	82.2	0.25	9:00 am	9:53 am
2 – Sand*	JMM + sand	0.14**	82.5			
3	JMM pre-packaged material	0.16	84	0.125	12:26 pm	12:45 pm

*Layer 2 was split into two sections: one side containing LWA and the other side containing sand.
**W/cm was adjusted to thicken to mixture to aide with place-ability of the second layer.

3.2.1.1 Layer 1

Prior to pouring the first layer, the work crew prepped the pavement surface by spraying it down with a water hose. No sand blasting or power washing was done to the surface. The placement of the first layer started at 7:30 a.m. and was completed at 7:52 a.m. (22 minutes of placement time). The JMM was mixed in a 5-gallon bucket with a handheld double-spindle mortar mixer.

To maintain a w/cm of 0.16, 25 lbs of JMM and 4 lbs of water were weighed out for each bucket mixed. Each bucket of JMM was dumped on the damp concrete pavement and was spread out with a squeegee, power-troweled from left to right, and then broomed to ensure even spread and texture. This batching process was repeated until the entire area was covered, and the first layer was uniformly 0.125 in. thick. The layer was left exposed to the air to dry; no curing measures were taken to cover the surface because it would delay the placement of the second layer.

Fresh property testing was conducted, and permeability samples were collected. The results from this testing are presented in the Results section. Images of the first layer are shown below.

Figure 3.17: Map Cracking of Concrete Substrate Prior to Overlay Placement

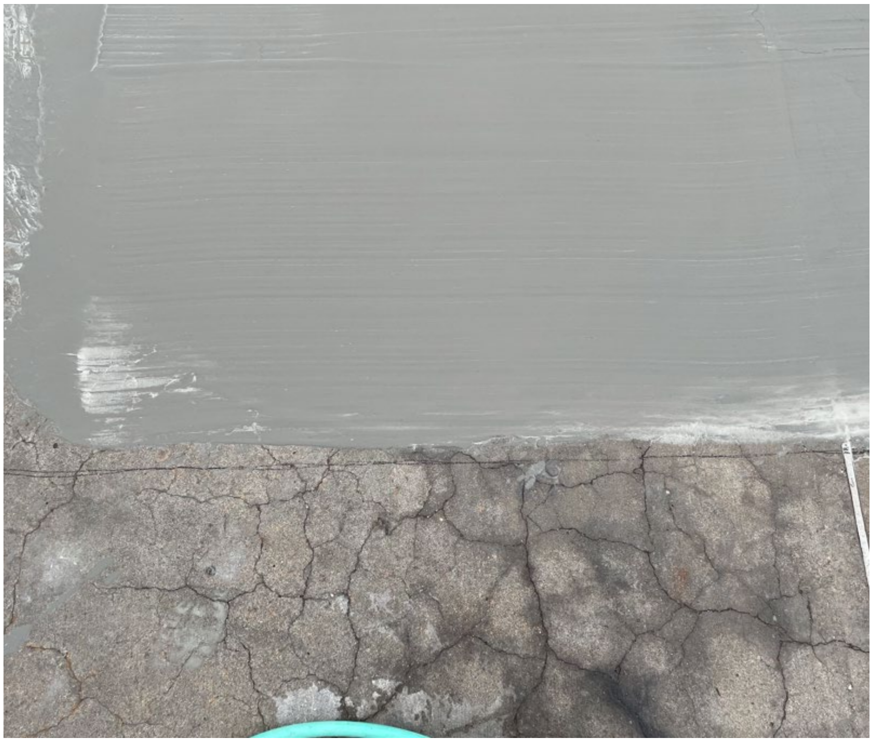


Figure 3.18: First Layer of JMM Overlay Applied to Surface of Map-Cracked Pavement

Figure 3.19: Spreading First Layer of JMM with Squeegee

Figure 3.20: Using Power-Trowel to Work JMM into Substrate

Figure 3.21: Smoothing and Adding Surface Texture with Broom

Figure 3.22: Completed First Layer of JMM Overlay

3.2.1.2 Layer 2

At the recommendation of the inventor, the first layer was allowed to dry for approximately 2.5 hours before the second layer was placed. No curing of the first layer was performed. Prior to pouring the second layer, the work crew sprayed the first layer with a water hose to facilitate bond between the layers. The placement of the second layer started at 9:00 a.m. and was completed at 9:53 a.m. (53 minutes of placement time). Since this layer needed to be 0.25 in. thick, the w/cm ratio was reduced to 0.14 and fine aggregate was added to the mixture to provide enough structural stability to build the layer up taller than the first layer. For the first two-thirds of the slab's length (~20 ft), LWA fines were added to each JMM mixture (0.25 in. x 00 gradation). Then in the remaining one-third length (~10 ft), Nebraska sand was added to each JMM mixture (NMAS = 1/4 in.).

Like the first layer, the JMM was mixed in a 5-gallon bucket with a handheld double-spindle mortar mixer. To maintain a w/cm of 0.14, 25 lbs of JMM and 3.6 lbs of water were weighed out for each batch mixed. Each batch of the Jay's Majic Mud was dumped on the dampened first layer and was spread out with a squeegee and levelled off with the vibrating screed. This was repeated until the entire area was covered, and the layer was 0.25 in. thick.

Fresh property testing was conducted, and permeability samples were collected. Samples were also collected to conduct a hardened air analysis, and these results are shown in **Appendix C**. The results from this testing are presented in the Results section. Images of the second layer are shown below.

Figure 3.23: Placing JMM in Front of Homemade Vibrating Screed

Figure 3.24: Moving Vibrating Screed Along Slab to Consolidate and Smooth JMM

Figure 3.25: Completed Second Layer of JMM Overlay

Figure 3.26: Plastic Shrinkage Crack on Surface of Layer 2

Figure 3.27: Plastic Shrinkage Crack on Surface of Layer 2

3.2.1.3 Layer 3

Prior to placing the third layer, the second layer was allowed to dry, and no curing was performed. The work crew sprayed the second layer with a water hose to aid with bond between layers, and then the third layer was poured. The placement of the third layer started at 12:26 p.m. and was completed at 12:45 p.m. (19 minutes of placement time).

Again, JMM was mixed in a 5-gallon bucket with a handheld double-spindle mortar mixer. To maintain a w/cm of 0.15, 25 lbs of JMM and 3.8 lbs of water were weighed out for each batch mixed. Each batch of the JMM was dumped on the dampened second layer and was spread out with a squeegee, power troweled, and then broomed to ensure even spread and texture. This was repeated until the entire area was covered, and the layer was 0.125 in. thick. After the third layer had set up a bit, the surface was tined with a rake to add texture to the finished surface.

No fresh or hardened property testing was done on this layer since it was the same mixture design as Layer 1, on which testing was already done. Images of the third layer are shown below.

Figure 3.28: Timeline Breakdown of the Placement of Layer 3

Figure 3.29: Completed Third Layer of the JMM Overlay

3.2.2 Sample Preparation, Conditioning, and Testing

After preparing the JMM mixtures for each layer, fresh properties of the concrete were tested, which included unit weight (ASTM C138, 2017) and air content (ASTM C231, 2017). Then samples were prepared for surface resistivity (SRM) (KT-79 Kansas Test Method, 2018), volume of permeable voids (KT-73 Kansas Test Method, 2018), and rapid chloride permeability (RCP) (AASHTO Standard T277, 2011).

All cylinders prepared for hardened property testing were field cured on the job site for the first 24 ± 2 hours according to KT-22 Kansas Test Method (2018). The cylinders were kept in their molds during this time and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were cut and tested for volume of permeable voids (KT-73 Kansas Test Method, 2018) and rapid chloride permeability (AASHTO Standard T277, 2011). Prior to being cut and tested, the 28-day and 56-day SRM of the cylinders was measured per KT-79 Kansas Test Method (2018). Eight readings were taken on each cylinder and were averaged to report a single resistivity value.

3.2.3 Pull-Off Testing

Approximately three months after the trial placement of Jay's Majic Mud was completed, the KDOT Research team conducted concrete pull-off testing to measure the direct tensile strength of the overlay interface according to ASTM C1583 (2020). Six 2-inch diameter cores were drilled into different locations of the overlay. The following figures show schematics of the core locations where the pull-off testing was conducted in the overlay. Then, pull-off testing was done on each core and the results are shown in the Results section. Photos of each core after pull-off testing can be found in **Appendix C**.

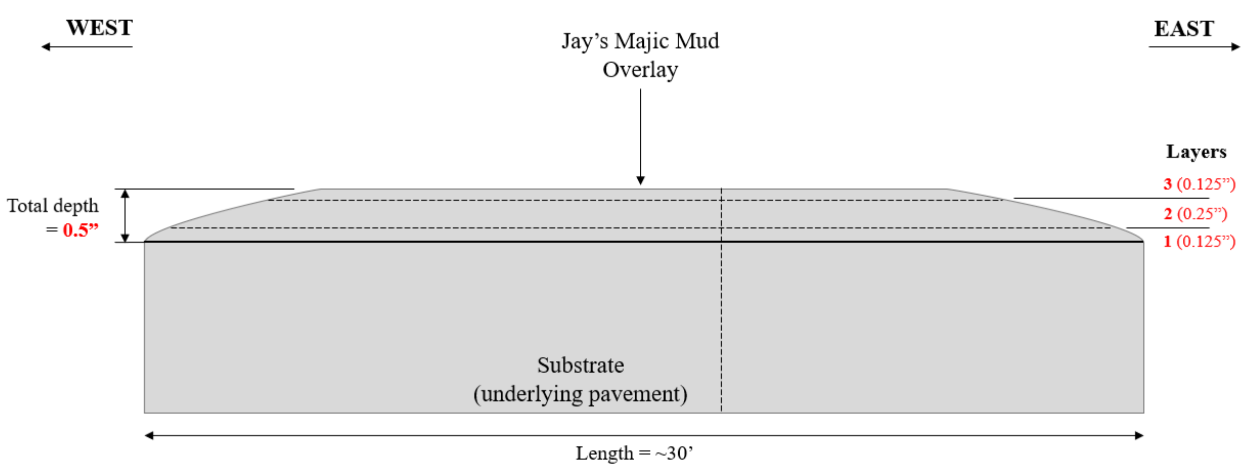


Figure 3.30: Elevation Schematic of JMM Overlay Thickness (Not Drawn to Scale)

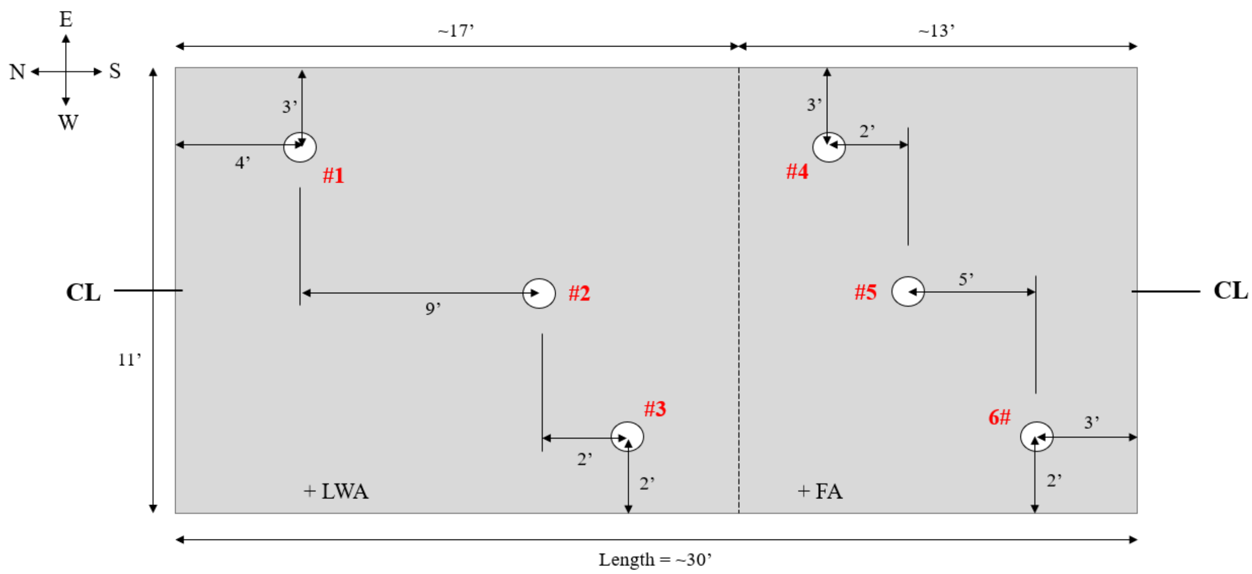


Figure 3.31: Top View Schematic of JMM Overlay Showing Core Locations (Not Drawn to Scale)

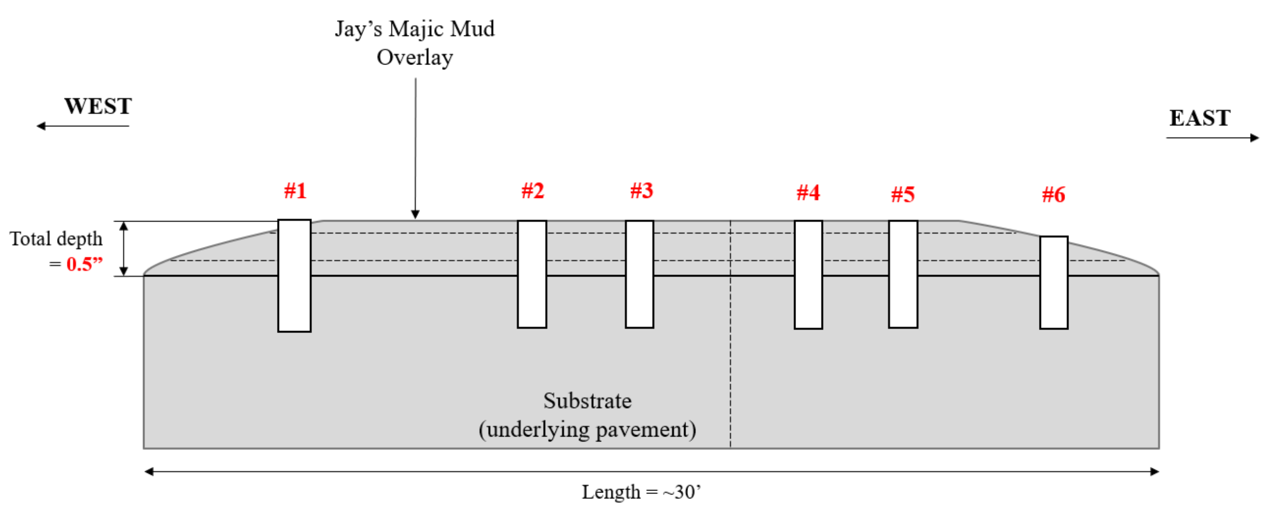


Figure 3.32: Elevation View Schematic of Core Locations (Not Drawn to Scale)

3.2.4 Results and Discussion

3.2.4.1 Fresh Property Results

Table 3.3 presents the fresh property test results from the JMM trial placement. Fresh properties were not tested on Layer 3 because it was the same mixture design as Layer 1 and was already measured. Fresh properties were not tested on Layer 2 with sand added due to the stiffness of the mix.

Table 3.3: Fresh Property Results of Trial Placement

Layer	Unit Weight (lbs/ft^3)	Air Content (%)
1	120.0	16.0
2 – LWA	124.9	12.0
2 – Sand	--*	--*
3	--*	--*

*Testing not conducted for this layer type.

According to Table 3.3, JMM has a lower unit weight than conventional concrete, which typically weighs 145 to 150 lbs/ft^3. Also, JMM has a much higher air content than conventional air-entrained concrete with 6.5% air. The fact that JMM naturally contains 12% to 16% could lead to poor strength and permeability performance; if the air inside the JMM mixtures is interconnected in structure, it will allow water and chemicals to easily flow through it and lead to rapid deterioration.

The air content decreased from 16% to 12% after LWA was added to the JMM mixtures. One possible reason for the decrease in air content after the addition of LWA could be because a portion of the JMM powdered material was removed from the mix design to account for the volume of LWA being added to the mixture. If the JMM material contains constituents with air-entraining properties, removing some of the material from the mixture would decrease the apparent air content.

3.2.4.2 Permeability Results

The results of the permeability testing from the JMM trial pour are presented in the figures and table below. Standard deviation error bars are also shown for each layer type. The figures include the KDOT permeability requirement limits for each test method and refer to the values presented in Table 2.10. Table 3.4 summarizes the overall permeability performance of the JMM trial pour according to Section 402-1 of the KDOT (2015) Standard Specifications.

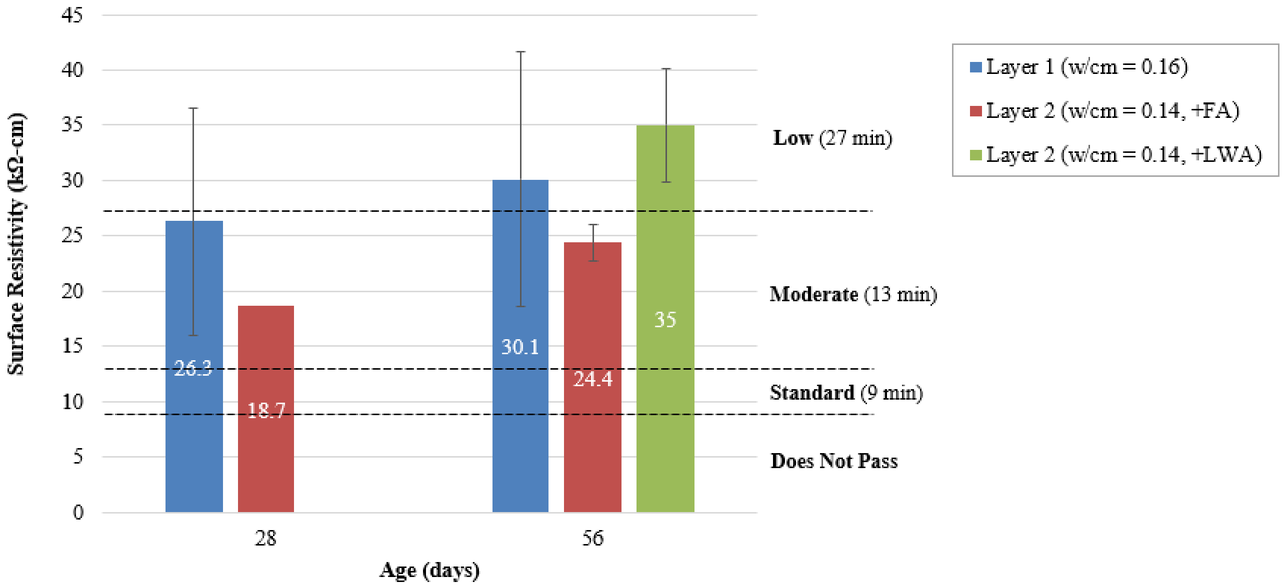


Figure 3.33: Surface Resistivity (KT-79) Results from Trial Pour

According to Figure 3.33, Layer 1 met and nearly exceeded the surface resistivity (SRM) criteria for Moderate Permeability at 28 days. Layer 2 + FA also met the SRM requirements for Moderate Permeability at 28 days. To be used as a bridge deck overlay material, JMM needed to meet the SRM requirements for Low Permeability (minimum of 27 kΩ-cm) at 28 days. Unfortunately, neither Layer 1 nor Layer 2 met this requirement.

To assess how JMM's resistivity performance changes over time, SRM was also tested at 56 days. Layer 1 was able to meet the requirements for Low Permeability at 56 days. However, Layer 2 + FA only met Moderate Permeability requirements. Layer 2 + LWA was only tested for 56-day SRM and greatly exceeded the criteria for Low Permeability. If this layer followed similar surface resistivity trends as the other two layers, it most likely would have met the SRM requirements of Low Permeability at 28 days. These results seem to show that the addition of LWA can improve the permeability performance of JMM because of the addition of internal curing water producing a better (more dense) final paste matrix.

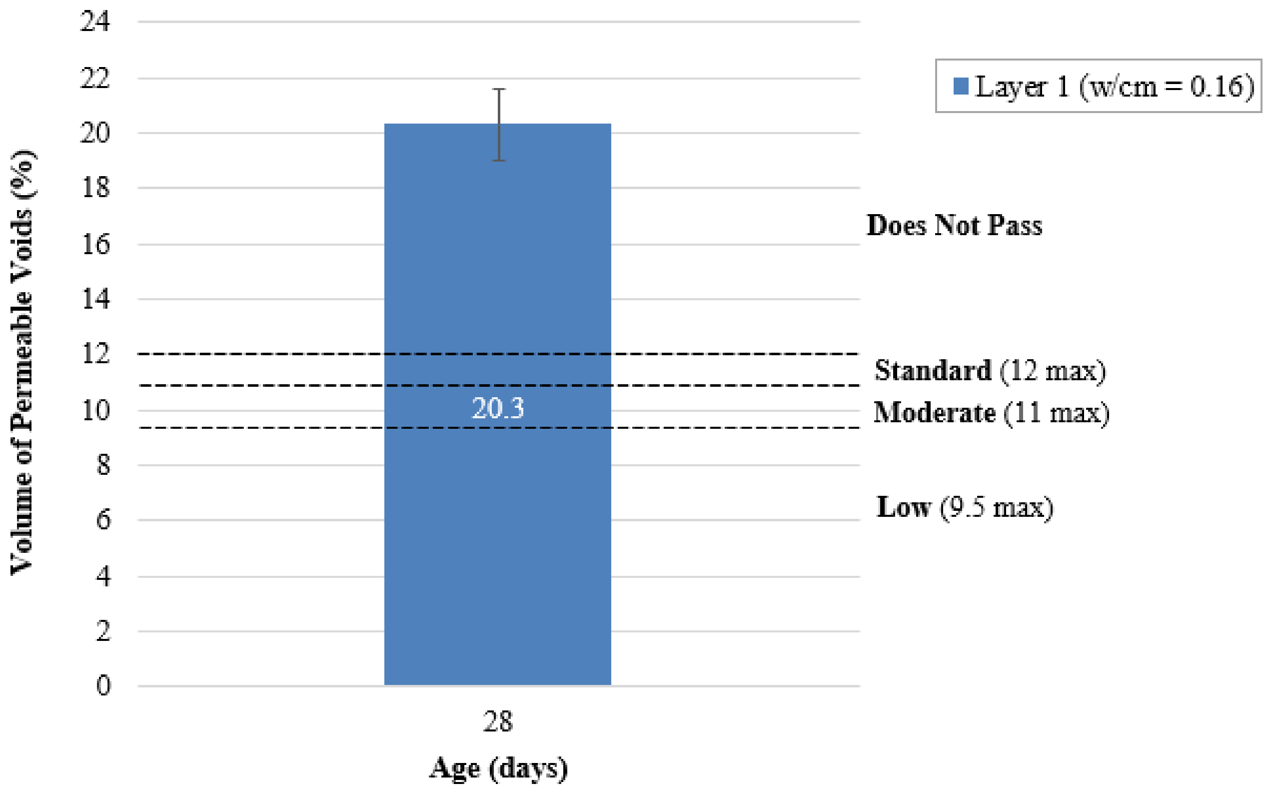


Figure 3.34: Volume of Permeable Voids (KT-73) Results from Trial Pour (No Results for Layer 2)

According to Figure 3.34, Layer 1 did not meet any of KDOT's permeability requirements for volume of permeable voids. Unfortunately, no volume of permeable void testing was conducted on Layer 2 + FA or Layer 2 + LWA due to job constraints.

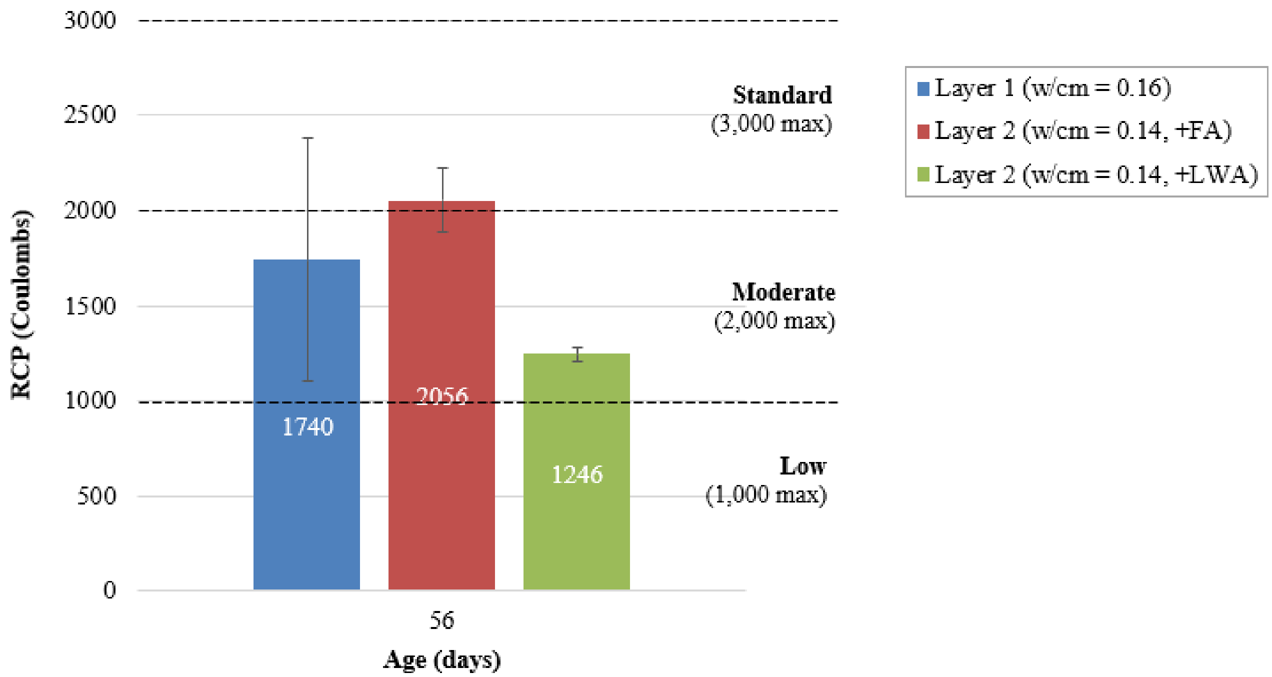


Figure 3.35: Rapid Chloride Permeability (AASHTO T-277) Results from Trial Pour

According to Figure 3.35, Layer 1 and Layer 2 + LWA met the Moderate Permeability requirements for rapid chloride permeability (RCP) at 56 days, while Layer 2 + FA met the Standard Permeability requirements for RCP at 56 days. Unfortunately, to be used as an overlay material, Low Permeability performance is required.

Table 3.4: Summary of Permeability Performance According to Section 402-1

Layer	KT-79: 28-d SRM	KT-79: 56-d SRM	KT-73: 28-d Vol. of Perm. Voids	AASHTO T-277: 56-d RCP
1	Moderate	Low	Does not pass	Moderate
2 – LWA	--*	Low	--*	Moderate
2 – Sand	Moderate	Moderate	--*	Standard

*Testing not conducted for this layer type.

Overall, Layer 1 and Layer 2 + LWA exhibited better permeability performance than the other Layer 2 + Sand. Even though it meets Moderate Permeability according to 28-day SRM and RCP, it did not meet the volume of permeable voids requirements for any KDOT permeability classification. This is not surprising, since the fresh air content for Layer 1 was 16%, which is extremely high for even an air-entrained concrete mixture.

3.2.4.3 Pull-Off Results

The following table and figure present the results of the pull-off testing conducted on the JMM overlay.

Table 3.5: Pull-Off Testing Results of JMM Overlay

Core #	Tensile Strength (psi)	Depth of Break	Additional Information
1	N/A*	0.5"	Core broke during coring process at overlay-substrate interface
2	57.9	0.375"	Broke at overlay-substrate interface
3	5.7	1.75"	Broke in substrate
4	8.3	2.0"	Broke in substrate
5	16.6	0.375"	Broke at overlay-substrate interface
6	N/A*	0.5"	Core broke during coring process at overlay-substrate interface

*Core broke during coring process, so tensile strength data was not able to be recorded.

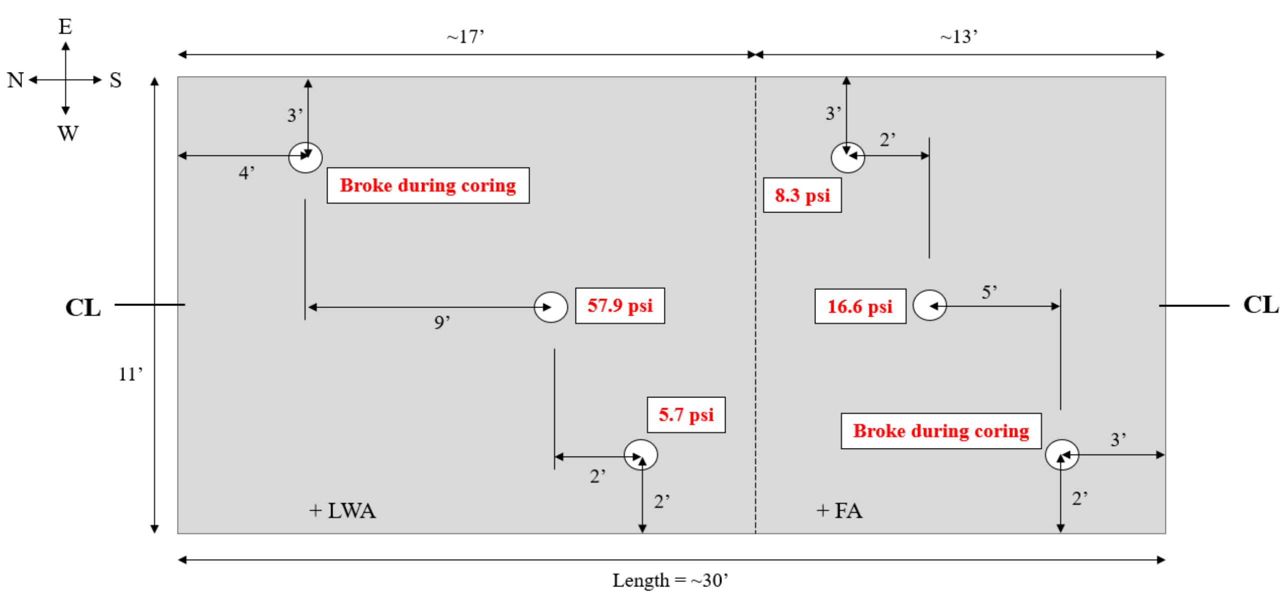


Figure 3.36: Top View Schematic of JMM Overlay Showing Tensile Strength Results of Each Core

According to Table 3.5 and Figure 3.36, four of the six cores broke at the overlay-substrate interface, while the other two cores broke in the substrate concrete. The cores that broke at the interface broke at a higher tensile force than the cores that broke in the substrate concrete. This is an odd result and could mean that the substrate concrete at these core locations had poor strength and/or durability, which led to the premature breaking.

The cores that broke at the interface broke at tensile forces of 57.9 psi and 16.6 psi. Bond strengths for conventional overlay systems would be expected to be in the range of 150 to 250 psi, which is significantly higher than the JMM overlay system. Conventional overlays are typically placed on machine-prepared surfaces that are textured to improve surface bond. The only surface preparation that was done to the substrate concrete prior to placing the JMM was spraying it down with a hose; no sand blasting or power washing was done to the surface. This lack of surface preparation could be one reason for the poor pull-off testing performance. Future testing could be done to assess the direct tensile strength of the bond interface when different surface preparation techniques are used.

3.2.5 Conclusions

According to the results discussed in the previous section, the following conclusions were made.

3.2.5.1 Fresh Property Conclusions

- JMM has an air content of 12% to 16%, which is much higher than the conventional air-entrained target of less than 10 percent.
- JMM has a unit weight of 120 to 125 lbs/ft^3, which is much lower than conventional concrete, which ranges from 145 to 150 lbs/ft^3.

3.2.5.2 Permeability Conclusions

- The addition of LWA to Layer 2 improved the surface resistivity performance of JMM over time.
- Layer 1 (w/cm = 0.16) and Layer 2 + LWA (w/c = 0.14) exhibited better permeability performance than the other layer types. Even

though it meets Moderate Permeability according to 28-day SRM and RCP, it does not meet the volume of permeable voids requirements for any KDOT permeability classification. Therefore, it cannot be used as a KDOT approved overlay material in its current form.

3.2.5.3 Pull-Off Testing Conclusions

- Bond strengths for conventional overlay systems would be expected to be in the range of 150 to 250 psi. The highest bond strength achieved at the overlay-substrate interface was 58 psi, which is significantly lower than what is expected of conventional overlays.
- Four of the six cores broke at the overlay-substrate interface. This shows that proper surface preparation of the substrate prior to placing the JMM is important to achieving a good bond at the interface.

3.3 Phase 2 Conclusions

After completing the Phase 2 investigation and testing, the following conclusions are summarized below:

- Plastic shrinkage cracking appears to be the most common issue for JMM overlays.
- Reflective cracking was noted at joints and seams of JMM overlays and is considered normal with this type of thin overlay. Several areas on existing JMM projects exhibited surface spalling where substrate deterioration might not have been addressed before overlaying.
- JMM has an air content of 12% to 16%, which is much higher than conventional air-entrained concrete which contains 6.5% air.

- JMM has a unit weight of 120 to 125 lbs/ft^3, which is much lower than conventional concrete, which ranges from 145 to 150 lbs/ft^3.
- The results from the trial placement show that JMM did not meet the Low Permeability requirements, which means that it cannot be approved by KDOT as an overlay material in its current form.

Chapter 4: Phase 3 – Investigation of Permeability-Enhancing Techniques

4.1 Permeability-Enhancing Admixture

Phase 3 of this study involved the investigation of techniques to enhance the permeability of Jay's Majic Mud (JMM). The previous two phases of this research have shown that JMM by itself has undesirable permeability. The main application for JMM in the field is overlays—both small- and large-scale. Bridge deck overlay mixtures must meet the criteria for Low Permeability outlined in Section 402-1 of the KDOT (2015) Standard Specification. For KDOT to allow JMM to be used as an overlay material for state jobs, it must meet the Low Permeability requirements specified in the Standard Specifications.

In this study, a liquid admixture called Moxie Shield 1800 was added to JMM mixtures to determine whether it could improve the permeability of JMM. Moxie Shield 1800 is a liquid admixture formulated to stop moisture vapor, water migration, and alkali florescence in concrete mixtures (Moxie International, 2019). It creates a complex chemical reaction by converting the by-products of cement hydration into a higher density cementitious material, thus creating an impermeable substrate (Moxie International, 2019). A data sheet for Moxie Shield 1800 is included in **Appendix D**.

4.1.1 Materials and Mixture Information

Laboratory mixtures were made with Jay's Majic Mud (JMM) pre-packaged material at the KDOT Materials and Research Center in Topeka, Kansas. Two mixture designs were investigated and are shown in Table 4.1. Moxie Shield 1800 was added to each mixture to determine whether the permeability performance of JMM could be improved or not. The dosage rate used in this study is what Moxie International recommends for normal use and is shown in Table 4.1.

Both mixtures were designed to have a w/cm = 0.16, which is the w/cm recommended by the producer to achieve the optimal flow properties for typical JMM applications. However, due to the amount of accelerator added to the second mixture (5 lbs per 50 lbs of JMM), the mixture began to rapidly set up. To attempt to counteract the rapid set and improve the workability of the mixture, additional mixing water was added, and the final w/cm is documented in Table 4.1.

Table 4.1: Overview of JMM Mixtures

Mixture ID	Description	W/cm	Additives
3# Accel + Moxie (w/cm = 0.16)	JMM + non-chloride accelerator + Moxie admixture	0.16	3 lbs of accelerator per 50 lbs of JMM 300 oz/yd^3 of Moxie Shield 1800**
5# Accel + Moxie (w/cm = 0.28)	JMM + non-chloride accelerator + Moxie admixture	0.28*	5 lbs of accelerator per 50 lbs of JMM 300 oz/yd^3 of Moxie Shield 1800**

*This mix was designed at a w/cm = 0.16, but additional mixing water was needed due to the rapid stiffening of the mixture.

**Dosage rate recommended by the Moxie Shield producer.

4.1.2 Sample Preparation, Conditioning, and Testing

Due to having a limited amount of material, no fresh property testing was conducted on the two JMM mixtures. For hardened property testing, samples were prepared for surface resistivity (KT-79 Kansas Test Method, 2018), volume of permeable voids (KT-73 Kansas Test Method, 2018), and rapid chloride permeability (RCP) (AASHTO Standard T277, 2011). The number of samples with the test method is summarized in Table 4.2 and additional information about sample preparation and testing can be found in the proceeding subsections.

Table 4.2: JMM Concrete Testing Information

Test Property	Test Method	Sample Size	Sample Count
Surface Resistivity (SRM)	KT-79	4 x 8 in. cylinder	3 per test (1, 14, 21, and 28 d)
Volume of Permeable Voids (Boil Test)	KT-73	2 in. puck (Cut from 4 x 8 in. cylinder)	3 (28 d)
Rapid Chloride Permeability (RCP)	AASHTO T-277	2 in. puck (Cut from 4 x 8 in. cylinder)	3 (56 d)

Three 4 x 8 in. concrete cylinders were made and cured according to KT-22 Kansas Test Method (2018) for volume of permeable voids testing (KT-73 Kansas Test Method, 2018). The cylinders were kept in their molds for the first 24 ± 2 hours and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were cut down to 2-in.-thick pucks and tested for 28-day volume of permeable voids.

Three 4 x 8 in. concrete cylinders were made and cured according to KT-22 Kansas Test Method (2018) for rapid chloride permeability (RCP) testing (AASHTO Standard T277, 2011). The cylinders were kept in their molds for the first 24 ± 2 hours and then demolded. After demolding, the cylinders were lab-cured in an environmentally controlled room at a temperature of 73 ± 3 °F and 100% relative humidity until they were cut down to 2-in.-thick pucks and tested for 56-day RCP. Prior to being cut and tested, the surface resistivity of all three cylinders was measured per KT-79 Kansas Test Method (2018) at 1, 14, 21, and 28 days. Eight readings were taken on each cylinder and were averaged to report a single resistivity value.

4.1.3 Results and Discussion

The following graphs show the electrical resistivity results, volume of permeable voids results, and rapid chloride permeability results for the JMM mixtures. Both mixtures generated a lot of heat during mixing and set up rapidly. The second mixture that contained 5 lbs of accelerator was extremely difficult to work with, so additional mixing water was added until it became workable enough to collect samples. Because of this additional water, the permeability performance of this JMM mixture was likely affected.

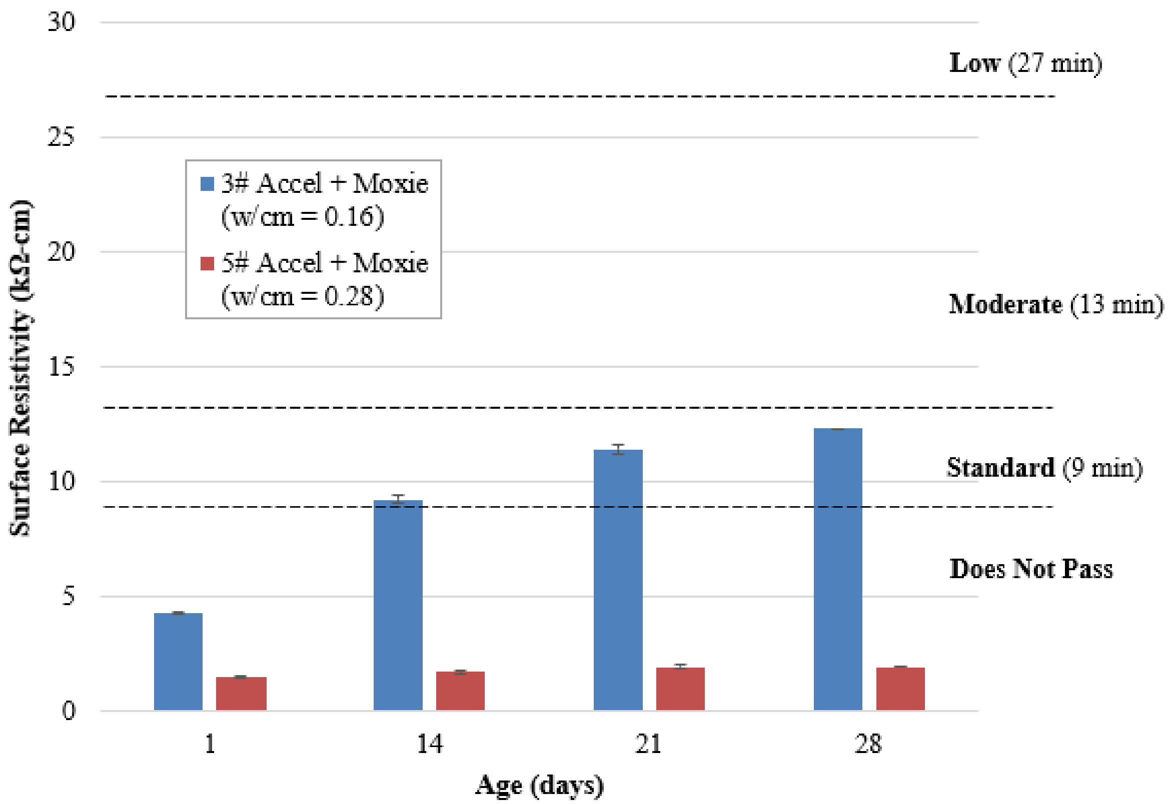


Figure 4.1: Surface Resistivity (KT-79) Results

According to Figure 4.1, the mixture with 3 lbs of accelerator was able to reach Standard permeability criteria at for SRM at 28 days, but the mixture with 5 lbs of accelerator did not come close to reaching the minimum KDOT Permeability requirements for SRM. This reduced performance was likely due to the additional water added during batching.

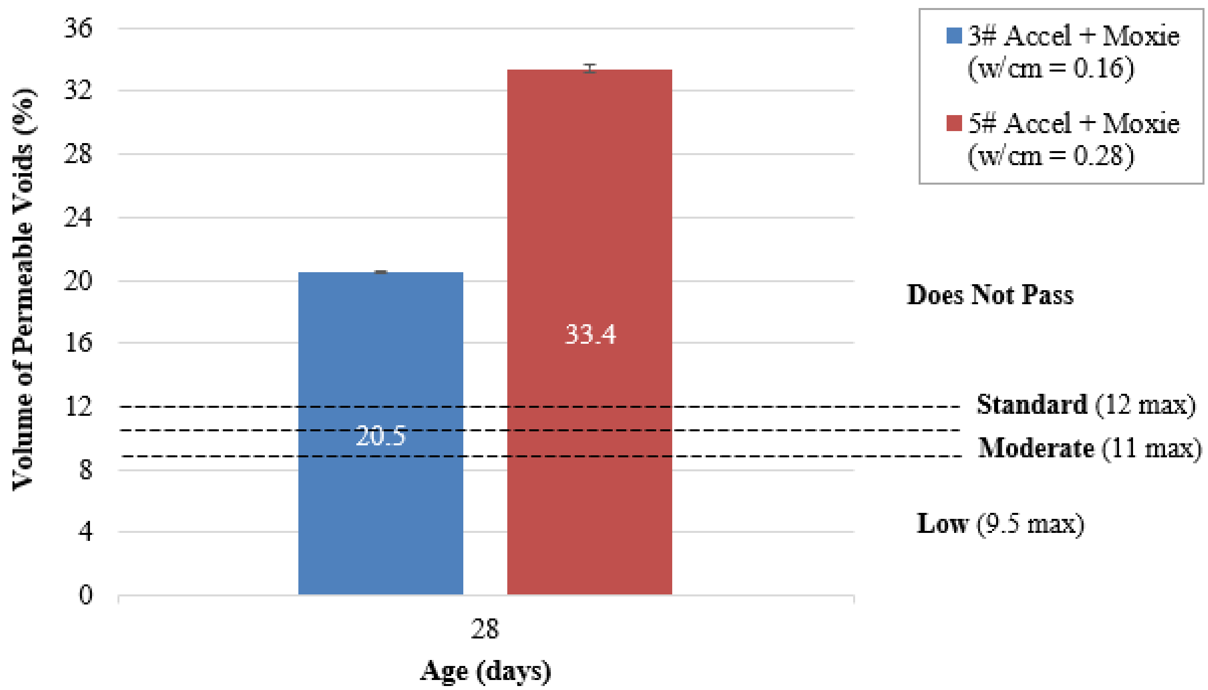


Figure 4.2: Volume of Permeable Voids (KT-73) Results

According to Figure 4.2, both mixtures exceeded the KDOT permeability requirements for volume of permeable voids. The high percentage of volume of permeable voids measured in both mixtures suggests a large amount of connected void spaces inside the paste matrix. Having a lot of connected voids inside concrete is not favorable, as that corresponds to a high level of permeability.

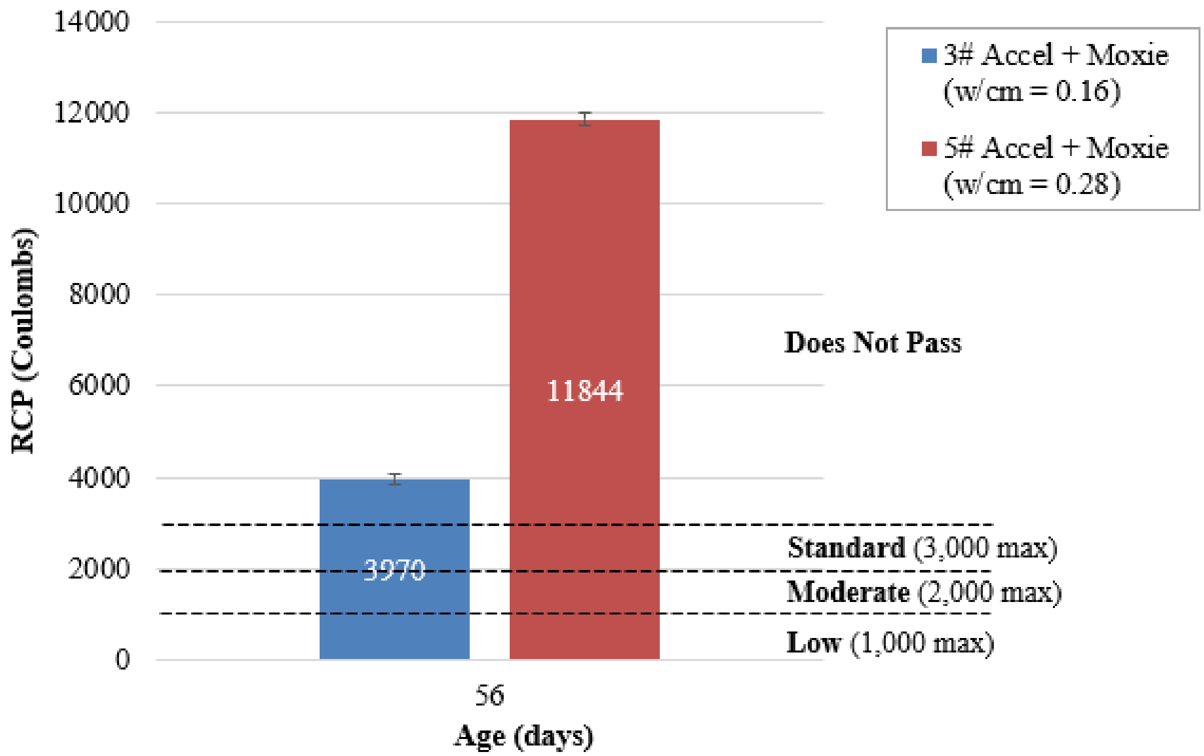


Figure 4.3: Rapid Chloride Permeability (AASHTO T-277) Results

According to Figure 4.3, both mixtures exceeded the KDOT permeability requirements for RCP. The mixture with 5 lbs of accelerator added exceeded the maximum RCP limit by nearly 9,000 coulombs, which suggests extremely poor permeability performance. This reduced performance is likely due to the additional water added during batching.

Table 4.3: Summary of Permeability Performance According to Section 402-1

Mixture ID	KT-79: 28-d SRM	KT-73: 28-d Boil	AASHTO T-2-77: 56-d RCP
3# Accel + Moxie (w/cm = 0.16)	Standard	Does not pass	Does not pass
5# Accel + Moxie (w/cm = 0.28)	Does not pass	Does not pass	Does not pass

Table 4.3 summarizes the KDOT permeability performance according to Section 402-1 of the Standard Specifications (KDOT, 2015). It is apparent that the addition of Moxie Shield 1800 did not improve the permeability performance of these two JMM mixtures. This poor performance

was expected of the second mixture due to its high w/cm ratio, but the first mixture was expected to have more favorable performance due to the Moxie Shield 1800 admixture.

One factor that could have influenced the permeability performance of the mixtures was poor workability. Both mixtures immediately began to set up during mixing due to the added accelerator and heat caused from the mixing process. While samples were being made, the mixtures were extremely stiff and difficult to work with, which could have led to unfavorable consolidation and compaction of material in the cylinder molds. Proper consolidation is necessary to remove entrapped air voids in the concrete and improve the permeability and durability performance. Poor consolidation of concrete mixtures can leave large unwanted void spaces and negatively impact the performance of the concrete. This could be a partial reason for the poor performance of the JMM mixtures in this phase of the study.

Future work is necessary with normal JMM material and Moxie Shield 1800 (no accelerator added) to assess the permeability performance of plain JMM mixtures. The mixtures in this phase of the research were used because it was all the JMM that was left after the first two phases of testing.

4.1.4 Conclusions

According to the results presented in the previous section, the following conclusions were made:

- Neither JMM mixture was able to meet all the KDOT permeability requirements (surface resistivity, volume of permeable voids, and rapid chloride permeability).
- Additional testing with plain JMM and Moxie Shield 1800 is necessary to assess whether the admixture could improve the permeability performance of JMM.

Chapter 5: Conclusions and Recommendations

After conducting three phases of research on Jay's Majic Mud (JMM) material, the following conclusions and recommendations are summarized below:

- Mixing JMM at the recommended water/cement ratio of 0.16 is critical to obtaining desired strength results. Any increase in w/c ratio will reduce strength. However, even when mixed at the optimum w/c ratio of 0.16, JMM does not meet the strength requirements to be prequalified by KDOT as a rapid hardening cement. It also does not meet the physical requirements to be prequalified as a blended cement (Type IP).
- JMM lacks the low permeability required to be used as a KDOT bridge overlay material when mixed neat. Therefore, JMM cannot be used in its current pre-packaged form as a standalone bridge overlay material according to KDOT's Standard Specifications.
- The long-term performance of a JMM overlay, as with any thin bonded overlay, is directly related to the condition of the substrate it is placed on; therefore, careful substrate preparation and/or repair of the substrate before placement is critical. Any existing delaminated concrete, areas of heavy cracking, or other damaged substrate locations, should be fixed by partial or full depth patching prior to placement of the JMM thin overlay system. If not repaired, those areas of distress will reflect up through the JMM overlay. Heavy map cracks should be epoxy sealed before the placement of the JMM thin system to help arrest the map cracking.
- The JMM thin overlay system has great potential for use in restoration of light or moderate traffic use areas such as parking lots, driveways, public sidewalks, entrances, stairways, walls, slabs, floors, etc. With trained manpower, it can be batched and placed with minimal equipment and facility downtime and can adjust to solve a variety of surface or grade problems typically encountered in facilities that have been already in

service for several years. JMM can be used to easily restore damaged surfaces or slightly misaligned surfaces back to normal, eliminating in many cases what would otherwise be costly and unnecessary safety hazards for the owner, or costly full depth replacements of sidewalks or slabs.

- When prewetted lightweight aggregate (LWA) is added during batching, the permeability of JMM was lowered and the freeze-thaw durability increased greatly. Although this does add an extra ingredient and cost to the batching process, it does show the merit of this method for helping to internally cure the paste and improve durability while also reducing plastic shrinkage cracking.

Chapter 6: Additional Testing Completed & Future Testing

On August 30, 2023, additional testing was completed evaluating two mix variants using JMM with the addition of a powdered waterproofing admixture provided by Jay's friend Bob, from Ash Grove. This was added to each mix at 2.6% by mass of JMM. The w/c for each mix was 0.16.

The control mix (MRC Lab # 23-1156) utilized JMM (neat) + 2.6% by mass of the powdered waterproofing admixture. In the second mix (MRC Lab # 23-1155) used an additional 13% pre-wetted lightweight fine aggregate in addition to the 2.6% by mass of the powdered waterproofing admixture to evaluate the potential improvements in permeability.

The results for both mixes are listed below, and the lowest permeability any test was able to meet was Moderate Permeability. Because neither of these mixes meet the Low Permeability requirement, this product cannot be used as a thin bonded bridge deck overlay mix in Kansas.

Table 6.1: Additional Test Results

Mix	Lab #	f'c (psi)	Boil (%)	SRM (kΩ-cm)	RCP (coulombs)
JMM + 2.6% WP Admix.	23-1156	5640	22.9 (DNM-SP)	18.5 (M-MPC)	1977 (M-MPC)
JMM + 2.6% WP Admix. + 13% LW	23-1155	5755	21.9 (DNM-SP)	14.6 (M-MPC)	2188 (M-SPC)

Key: DNM-SP = Does Not Meet Standard Permeability; M-MPC = Meets Moderate Permeability Concrete; M-SPC = Meets - Standard Permeability Concrete

No additional or future testing is planned for this product as of date. The investigation and evaluation of this new product is considered closed.

References

AASHTO Standard T277. (2011). *Standard method of test for electrical indication of concrete's ability to resist chloride ion penetration*. Washington, DC: American Association of State Highway and Transportation Officials.

ASTM C39/C39M-21. (2021). *Standard test method for compressive strength of cylindrical concrete specimens*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0039_C0039M-21, www.astm.org

ASTM C109/C109M-20b. (2020). *Standard test method for compressive strength of hydraulic cement mortars (using 2-in. or [50 mm] cube specimens)*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0109_C0109M-20B, www.astm.org

ASTM C138/C138M-17a. (2017). *Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0138_C0138M-17A, www.astm.org

ASTM C151/C151M-18. (2018). *Standard test method for autoclave expansion of hydraulic cement*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0151_C0151M-18, www.astm.org

ASTM C157/157M-17. (2017). *Standard test method for length change of hardened hydraulic-cement mortar and concrete*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0157_C0157M-17, www.astm.org

ASTM C185. (2020). *Standard test method for air content of hydraulic cement mortar*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0185-20, www.astm.org

ASTM C188. (2017). *Standard test method for density of hydraulic cement*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0188-17, www.astm.org

ASTM C191. (2021). *Standard test methods for time of setting of hydraulic cement by vicat needle*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0191-21, www.astm.org

ASTM C204-18e1. (2019). *Standard test methods for fineness of hydraulic cement by air-permeability apparatus*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0204-18E01, www.astm.org

ASTM C215. (2020). *Standard test method for fundamental transverse, longitudinal, and torsional resonant frequencies of concrete specimens*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0215-19, www.astm.org

ASTM C231/C231M-17a. (2017). *Standard test method for air content of freshly mixed concrete by the pressure method*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0231_C0231M-17A, www.astm.org

ASTM C430. (2017). *Standard test method for fineness of hydraulic cement by the 45-µm (No. 325) sieve*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0430-17, www.astm.org

ASTM C457/C457M-16. (2017). *Standard test method for microscopical determination of parameters of the air-void system in hardened concrete*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0457_C0457M-16, www.astm.org

ASTM C511. (2021). *Standard specification for mixing rooms, moist cabinets, moist rooms, and water storage tanks used in the testing of hydraulic cements and concretes*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0511-21, www.astm.org

ASTM C666/C666M-15. (2016). *Standard test method for resistance of concrete to rapid freezing and thawing*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0666_C0666M-15, www.astm.org

ASTM C928/C928M-13. (2013). *Standard specification for packaged, dry, rapid-hardening cementitious materials for concrete repairs*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C0928_C0928M-13, www.astm.org

ASTM C1583-C1583M-20. (2020). *Standard test method for tensile strength of concrete surfaces and the bond strength or tensile strength of concrete repair and overlay materials by direct tension (pull-off method).* West Conshohocken, PA: ASTM International. DOI: 10.1520/C1583_C1583M-20, www.astm.org

ASTM C1600/C1600M-19. (2020). *Standard specification for rapid hardening hydraulic cement*. West Conshohocken, PA: ASTM International. DOI: 10.1520/C1600_C1600M-19, www.astm.org

Kansas Department of Transportation (KDOT). (2015). *Standard specifications for state road & bridge construction*.

Kansas Department of Transportation (KDOT). (2018). Rapid hardening hydraulic cement (Special provision 15-20003). *Special provision to the* standard *specifications, 2015 Edition.*

KT-22 Kansas Test Method. (2018). Making and curing compression and flexural test specimens in the field. *Kansas Department of Transportation Construction manual, Part V*. Topeka, KS: Kansas Department of Transportation.

KT-73 Kansas Test Method. (2018). Density, absorption and volume of permeable voids in hardened concrete. *Kansas Department of Transportation Construction manual, Part V*. Topeka, KS: Kansas Department of Transportation.

KT-76 Kansas Test Method. (2018). Method for testing the compressive strength of molded cylindrical concrete specimens. *Kansas Department of Transportation Construction manual, Part V*. Topeka, KS: Kansas Department of Transportation.

KT-77 Kansas Test Method. (2018). Method for capping cylindrical concrete specimens. *Kansas Department of Transportation Construction manual, Part V*. Topeka, KS: Kansas Department of Transportation.

KT-79 Kansas Test Method. (2018). Surface resistivity indication of concrete's ability to resist chloride ion penetration. *Kansas Department of Transportation Construction manual, Part V*. Topeka, KS: Kansas Department of Transportation.

KTMR-22 Kansas Test Method. (2012). *Resistance of concrete to rapid freezing and thawing.* Topeka, KS: Kansas Department of Transportation.

McLeod, H. A., Welge, J., & Henthorne, R. (2014). *Aggregate freeze thaw testing and D-cracking field performance: 30 years later* (Report No. KS-14-04). Topeka, KS: Kansas Department of Transportation.

Moxie International. (2019). *Moxie Shield 1800 Admixture*. http://moxieshield.com/1800.html

Appendix A: Freeze-Thaw Performance Comparison

Table A.1: Freeze-Thaw Performance Comparison

ID	Mix No.	Cut/Uncut?	Cycles @ RDME = 95%	RDME % @ 660 Cycles	Pass or Fail? (KTMR-22)
JMM *(w/cm = 0.16)*	**3686**	**Uncut**	**37**	**0%**	**Fail***
Poor F/T Bridge Example (CB)	3695	Uncut	48	0%	Fail*
	3696	Cut	48	0%	Fail*
JMM *(w/cm = 0.16)*	**3685**	**Cut**	**64**	**0%**	**Fail***
Low-end F/T Bridge Example (Montana)	3717	Cut	73	0%	Fail*
	3716	Uncut	86	0%	Fail*
Low-end F/T Br. Example (199th)	3765	Uncut	87	0%	Fail*
Bad F/T Pavement Example	3638	Cut	160	84%	Fail*
Mid-range F/T Bridge Example (Sunflower)	3648	Cut	187	55%	Fail*
Bad F/T Pavement Example	3637	Uncut	189	88%	Fail*
Mid-range F/T Bridge Example (Sunflower)	3647	Uncut	208	54%	Fail*
JMM + LWA	**3687**	**Uncut**	**344**	**83%**	**Fail***
Moxie	3593	Uncut	407	87%	Fail*
	3594	Cut	430	87%	Fail*
Good F/T Pavement Example	3633	Uncut	929	100%	Pass
	3634	Cut	1029	100%	Pass
Very Good F/T Pavement Example (Gove)	3694	Cut	1267	100%	Pass
	3693	Uncut	1335	100%	Pass

*An OGCA aggregate source sample "Fails" this test when it reports an RDME value of less than 95% after 660 freeze-thaw cycles. 95% at 660 cycles is the minimum F-T durability requirement for OGCA aggregates in Kansas pavements. There is no current minimum requirement for concrete bridge deck aggregates, however a 90% Durability Factor (ASTM C666, Procedure B) is required at 300 cycles by KDOT for Rapid-Set Concrete Patching Material (Section 1716, 2015 Standard Specifications).

Appendix B: Cost-Benefit Comparison

Table B.1 summarizes the thickness, expected life (EL), price per square yard, and cost/EL ratio for the different materials commonly used for overlays. The cost/EL ratio is computed by dividing the price per square yard by the expected life of the material.

Table B.1: Cost Comparison of JMM to Common Overlay Materials

Material	Thickness (in.)	Expected Life, EL (years)	Price per Sq. Yd. ($/yd^2)	Cost/EL ($/yd^2/year)
Multi-Layer Polymer Overlay	--	10	$34.14	$3.41
Jay's Majic Mud	0.5	8*	$25 – $45	$3.15 – $5.63
Silica Fume Overlay	1.0	12	$51.85	$4.32
	1.5	15	$59.59	$3.97
Portland Cement Concrete Overlay	1.5	15	$60.50	$4.03
	1.75	15	$49.00	$3.27
	2.0	15	$67.40	$4.49
	2.25	15	$69.60	$4.64
Polyester Polymer Concrete Overlay	1.75	15	$225.00	$15.00

*This is an approximate estimate based on existing in-service JMM light traffic projects.

As shown above in Table B.1, Jay's Majic Mud is comparable to other overlay material prices in terms of cost per expected service life (cost/EL); however, without a full-scale test project job it is difficult to see what the final price per sq. yd. savings could be due to alternative construction practices.

Appendix C: Extra Information from JMM Trial Pour

Table C.1: Hardened Air Analysis Results for JMM Trial Pour

Layer	Air Content (%)	Specific Surface (in^{-1})	Spacing Factor (in)
2 - Sand	20.6	646.8	0.0062

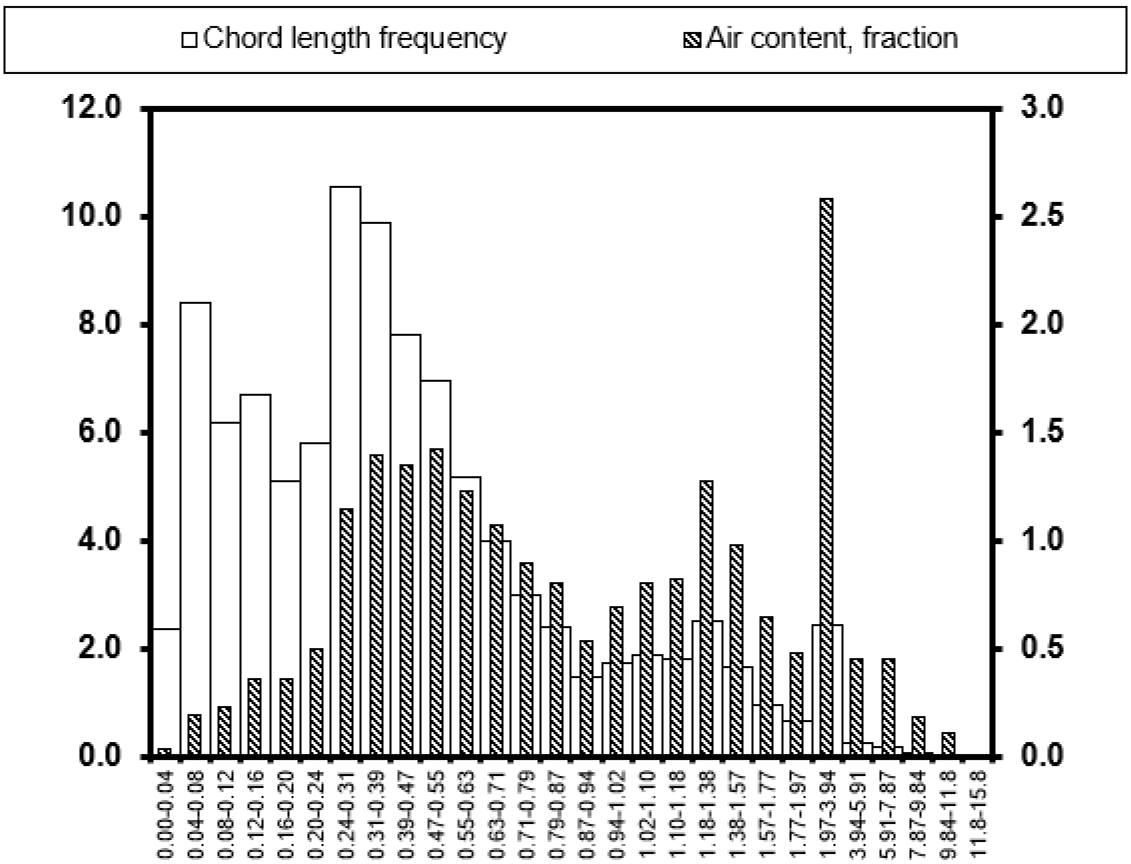


Figure C.1: Histogram of Chord Length Frequency and Air Content Fraction Distributions

Figure C.2: All Six JMM Cores After Pull-Off Testing

(a) (b)

Figure C.3: Core #1 After Pull-Off Test

(a) (b)

Figure C.4: Core #2 After Pull-Off Test

(a) (b)

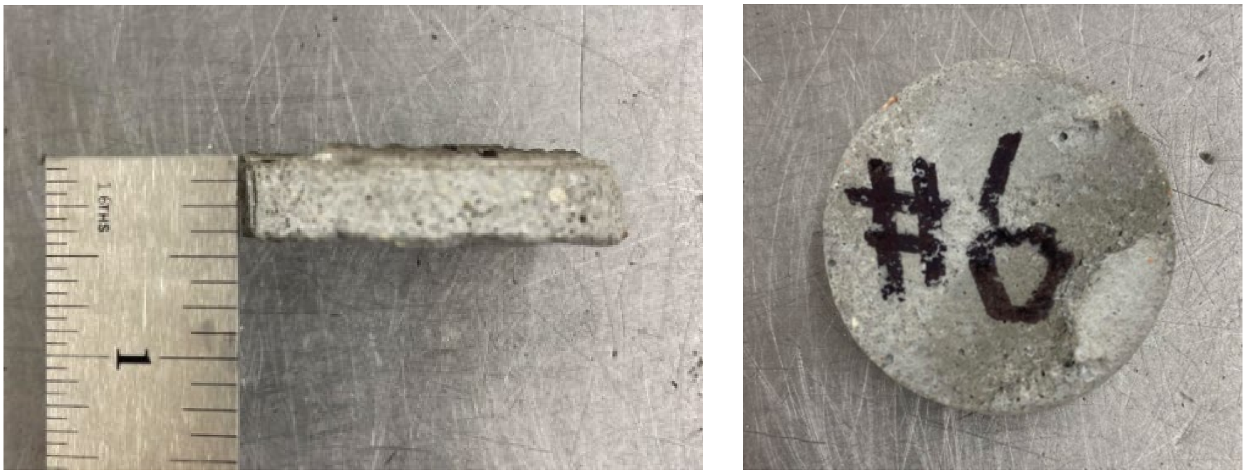
Figure C.5: Core #3 After Pull-Off Test

(a) (b)

Figure C.6: Core #4 After Pull-Off Test

(a) (b)

Figure C.7: Core #5 After Pull-Off Test



(a) (b)

Figure C.8: Core #6 After Pull-Off Test

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