DEPARTMENT OF TRANSPORTATION

Development of Mix Designs and Matrix of Materials for MnROAD Low Carbon Concrete Test Site

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NCE

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National Road Research Alliance

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16. Abstract (Limit: 250 words)

To address climate change mitigation goals, alternative concrete paving mixtures are being investigated that are claimed to have a lower global warming potential (GWP) at time of construction with equal or better long-term performance compared to conventional concrete paving mixtures currently in use by the Minnesota Department of Transportation (MnDOT). The objectives of this study are to develop a final matrix of test sections and a construction quality assurance (QA) plan for the construction of a Minnesota Road Research Facility (MnROAD) experimental section, consisting of 16 test cells, to assess the environmental impact and constructability of various concrete paving mixtures designed to reduce environmental impact, with the opportunity to assess in-service performance over a three-year period following test cell construction. This report documents the concrete mixtures being evaluated, the list of tests to be performed on the plant-produced concrete, construction observations, and a preliminary assessment of environmental impact. Follow-up studies are ongoing, which will document the lab testing results and provide yearly performance updates on the test cells. These reports will be made available by MnDOT.

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Final Report

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Executive Summary

To address climate change mitigation goals, state highway agencies are seeking alternative concrete paving mixtures that have a reduced embodied carbon content (ECC). However, most of the technologies used to reduce concrete ECC are relatively new to the market and research conducted on them has been primarily limited to small scale laboratory evaluations. This research project was initiated to develop a matrix of concrete mixture designs to be placed in 16 Minnesota Road Research Facility (MnROAD) test sections, develop a construction quality assurance (QA) plan, assess the constructability of various concrete paving mixtures designed to have reduced ECCs, and ultimately provide an opportunity to assess test results and in-service performance in coming years.

Mixture designs were selected for inclusion in the test matrix that met minimum engineering requirements to ensure constructability and performance. The final matrix included alternative cementitious materials (ACMs), alternative supplementary cementitious materials (ASCMs), and calcium carbonate mineralization. After selection, it was the responsibility of the material suppliers to work with independent accredited laboratories to trial batch mixture designs for use during construction. The project team reviewed the results of these mixture design studies to verify compliance with the pre-established mixture property requirements. The fresh concrete needed to be workable (i.e., able to be mixed, transported, placed, consolidated, and finished with minimal loss of homogeneity) for a minimum of 45 minutes. Specific hardened concrete properties were also required and were established through a combination of materials pre-approval and mixture testing.

Construction occurred in summer of 2022 and members of the research team were on-site during paving to assist with coordinating construction of the test cells and address any issues that could arise. Most of the mixtures had a higher water demand than originally anticipated, and a couple mixtures had some early setting issues, but nearly all of the mixtures were successfully placed. Some of these materials had never been run through a batch place, so some problems were anticipated. Additionally, most of these mixtures were not optimized for paving; it is reasonable to expect that all these materials could improve their performance for paving if optimized for that purpose.

A preliminary environmental assessment was conducted using what little data was available and provided by the material suppliers. The preliminary assessment showed that most mixtures were expected to have either a similar or lower ECC compared to the control mixture. A more in-depth assessment will be conducted as a part of future research projects that will aim to more accurately determine the ECC of each mixture.

At the time of this report, not all samples that were cast during paving have been tested. The preliminary results showed that, in general, most of the materials had similar performance compared to the control mixture. The test mixtures constructed as part of this study will be monitored after construction as part of three National Road Research Alliance (NRRA) research projects:

1. *Use of Alternative Pozzolanic Materials Towards Reducing Cement Content in Concrete Pavements*
2. *Use of Carbon Dioxide for Sustainable and Resilient Concrete Pavements*
3. *Alternative Cementitious Materials – Geopolymer Concrete*

Chapter 1: Introduction

1.1 Project Background

To address climate change mitigation goals, state highway agencies are seeking alternative concrete paving mixtures that have a reduced embodied carbon content (ECC)[1]. Several reduced ECC concrete paving mixtures have been investigated at the Minnesota Road Research Facility (MnROAD) to determine whether any have both a lower ECC at time of construction and equal or better long-term performance than a typical conventional concrete paving mixture used by the Minnesota Department of Transportation (MnDOT). The test mixtures in this study were placed at MnROAD in summer 2022, and they will be monitored after construction as part of three National Road Research Alliance (NRRA) research projects:

4. *Use of Alternative Pozzolanic Materials Towards Reducing Cement Content in Concrete Pavements*
5. *Use of Carbon Dioxide for Sustainable and Resilient Concrete Pavements*
6. *Alternative Cementitious Materials – Geopolymer Concrete*

1.2 Project Objectives, Purpose, and Need

The objectives of this study were to develop a matrix of mixture designs to be placed in 16 MnROAD test sections, develop a construction quality assurance (QA) plan, assess the constructability of various concrete paving mixtures designed to have reduced ECCs, and ultimately provide an opportunity to assess test results and in-service performance in coming years.

The scope of work consisted of the following tasks:

- Develop and finalize a test matrix
- Establish acceptance criteria
- Conduct a preliminary environmental assessment of each material
- Develop a construction quality assurance plan
- Provide consultation during the construction phase of the MnROAD test section
- Create this report documenting the project

[1] In this report, the term Embodied Carbon Content (ECC) represents the global warming potential (GWP) of the concrete mixture, expressed as $CO_{2\,eq}$. It reflects the greenhouse gas (GHG) emissions incurred in the production of the concrete from the start of production to the either when the concrete truck is batched and leaving the concrete plant (cradle-to-gate) or when the concrete is placed, consolidated, and finished (cradle-to-site).

Chapter 2: Matrix of Materials

The research team first focused on developing a matrix of reduced ECC concrete mixtures to be constructed and tested at MnROAD. The mixture designs selected for inclusion in the test matrix met minimum engineering requirements to ensure constructability and performance. Initially, the list of materials being considered was large and included alternative cementitious materials (ACMs), alternative supplementary cementitious materials (ASCMs), and calcium carbonate mineralization. After multiple discussions and iterations, a final matrix of 16 concrete mixtures was selected and approved by the SuperTAP. The following initial criteria were used to identify materials/technologies for consideration:

- The material producer had to be capable of delivering sufficient material to construct a nominally 270-ft long, 29-ft wide, 7.5-inch thick test cell.
- All mixtures were required to have specified fresh and hardened concrete properties, identified as part of this project.
- All mixtures were required to be batched and mixed in a conventional concrete plant, transported using conventional concrete trucks with a time to initial set of at least 45 minutes, and placed using a conventional slipform paver.
- All mixtures were required to have the potential to be market-ready, including scalable material availability, and the ability to be integrated into conventional concrete production and placement.
- Cooperation of the material supplier was required to conduct trial batching and demonstrate that the mixtures had the required properties.

After selection, it was the responsibility of the material suppliers to work with independent accredited laboratories to trial batch mixture designs for use during construction. The project team reviewed the results of these mixture design studies to verify compliance with the pre-established mixture property requirements.

The fresh concrete needed to be workable (i.e., able to be mixed, transported, placed, consolidated, and finished with minimal loss of homogeneity) for a minimum of 45 minutes. The properties of fresh concrete that were evaluated at the mixture design stage include those listed in

Table 1 along with the acceptance criteria.

Specific hardened concrete properties were also required and were established through a combination of materials pre-approval and mixture testing. The aggregate sources and admixtures used were pre-approved by MnDOT. For the aggregates, this included insurance of freezing and thawing durability and alkali-silica reactivity (ASR) durability. The mixture acceptance tests performed as part of the trial batching process, the acceptance criteria, and the required standard test procedures are shown in Table 2.

Table 1. Fresh concrete testing conducted at mix design stage

Standard Test	Requirement	Procedure
Slump	Report Only	AASHTO[1] T 119
Air Content	5 – 8%	AASHTO T 152
SAM	Report Only	AASHTO T 395
Unit Weight	Report Only	AASHTO T 121
Box Test	Report Only	AASHTO TP 137
Set Time	Report Only	ASTM[2] C403

[1] American Association of State Highway and Transportation Officials
[2] American Society for Testing and Materials

Table 2. Required hardened property tests at mix design stage

Standard Test	Requirement	Procedure
Flexural Strength	500 psi @ 28 days	AASHTO T 97
Compressive Strength	Report Only	AASHTO T 39
Maturity	Report Only	ASTM C1074

The Aggregate Industry aggregates used in this study were from a source pre-approved by the MnDOT for use in concrete pavement construction. Initially, 1 combination of aggregate sources (i.e., 1 ready mixed producer) was selected for preparing all mixtures[2].

The test matrix at the mixture design stage consisted of 16 cells total and the final test matrix is shown in Table 3. The concrete mixture designs for all cells are presented in Appendix A. A brief description of the materials used in each test cell follows. It should be noted that most of these mixtures were not optimized for paving;

[1] The CarbonCure™ mixtures were made by a different concrete supplier using different cement and aggregates than were used for the other materials.
[2] It was envisioned that a single combined source of aggregate from a single concrete supplier would be used in all mixtures. However, the concrete featuring calcium carbonate mineralization had to be sourced from a ready mixed producer other than the 1 selected for the rest of the construction. It is noted the 2 producers are in very close proximity and the lithology of each aggregate source is for all practical purposes identical.

instead, the producers chose to use the standard aggregate gradation and cementitious content. Those that did optimize did so for carbon reduction, not paving. It is reasonable to expect that these materials could improve their paving performance if optimized for that purpose.

Table 3. Low carbon concrete evaluated

MnROAD Cell #	Material Supplier[1]	Cementitious Materials and Content in Pounds per Cubic Yard (pcy)
2209	UltraHigh Materials 0% Portland clinker hydraulic cement	650 pcy cementitious
2210	CarbonCure™ Design Mixture With CO_2 injection	558 pcy cementitious 30% Coal Creek Class F fly ash Contains 6 oz. CO_2 per yard
2211	Control Mixture with CarbonCure™ With CO_2 injection	570 pcy cementitious 30% Coal Creek Class F fly ash Contains 6 oz. CO_2 per yard
2212	CarbonCure™ Design Mixture Without CO_2 injection	558 pcy cementitious 30% Coal Creek Class F fly ash
2213	Carbon Upcycling Processed fly-ash-based ASCM	500 pcy cementitious 30% treated ash
2214	Ash Grove Blended Cement Duracem® N Type IP(30)	570 pcy cementitious 30% calcined clay
2215	Urban Mining Pozzotive® ground-glass pozzolan	570 pcy cementitious 30% ground-glass ASCM
2216	Terra CO2 OPUS manufactured ASCM	570 pcy cementitious 35% ASCM
2217	CarbonCure™ Control Without CO_2 Injection	570 pcy cementitious 30% Coal Creek Class F fly ash
2218	Standard MnDOT Paving Mixture Study control	570 pcy cementitious 30% Coal Creek Class F fly ash
2219	Optimized Concrete Mixture	501 pcy cementitious 30% Coal Creek Class F fly ash
2220	Burgess Pigment Metakaolin Class N natural pozzolan	570 pcy cementitious 12% metakaolin natural pozzolan and 18% Coal Creek Class F fly ash
2221	3M™ Class N natural pozzolan from shingle baghouse fines	570 pcy cementitious 15% 3M natural pozzolan and 15% Prairie State Plant Class F fly ash
2222	Hess Pumice Pumice Class N natural pozzolan	570 pcy cementitious 30% pumice natural pozzolan
2223	Continental Blended Cement Type IL(20)	570 pcy cementitious 30% Coal Creek Class F fly ash

2224	Carbon Limit Ground limestone-pozzolan-proprietary additive blended ASCM	570 pcy cementitious 30% Carbon Limit ASCM

AASHTO M 240 Type IL blended cement has less embodied carbon than equivalent AASHTO M 85 Portland cement, as additional limestone is interground with the clinker during manufacturing. The primary cement used was an AASHTO M 240 Type IL(8) Portland-limestone cement (PLC) provided by the Holcim Ste. Genevieve Plant in Ste. Genevieve, MO (mill certificate provided in Appendix A). The calcium carbonate mineralization mixtures were made with Continental Davenport Type IL(10). The AASHTO M 295 Class F fly ash was from the Coal Creek Power Plant in Underwood, ND (mill certificate provided in Appendix A) and was added to mixtures at 30% by weight of total cementitious materials, unless otherwise noted. The total cementitious materials content is 570 pcy, unless otherwise noted.

Various chemical admixtures were used in the study to address the unique nature of each material. Table 4 summarizes the admixture product, type, and dosage used for each mixture during batching.

Table 4. Admixture type and dosage used in each mixture

Material	Admixture (Type)	Admixture Dosage fl oz per 100 lbs cement
UltraHigh	Sika[1] Air 260 (Air Entrainer) Sika Visocrete 1000 (High-range Water Reducer) Sika Sikatard 440 (Hydration Controller) Sika Stabilizer 4R (Viscosity Modifier)	As Needed 1 – 3 2 – 8 1 – 7
All CarbonCure Mixtures	MBS[2] Micro Air 90 (Air Entrainer) MBS Polyheed 1020 (Mid-range Water Reducer) MBS Master Matrix 358 (Viscosity Modifier) MBS Master Set Delvo (Extended-set Controller) MBS MasterSure Z 60 (Workability Retainer)	0.1 – 10 1 – 12 0 – 6 0 – 3 0 – 12
Carbon Upcycling	Sika Air 260 (Air Entrainer) Sika Visocrete 1000 (High-range Water Reducer) Sika Sikatard 440 (Hydration Controller) Sika Stabilizer 4R (Viscosity Modifier	3 0.2 2 1
Ash Grove IP(30)	Sika Air 260 (Air Entrainer) Sika Visocrete 1000 (High-range Water Reducer) Sika Sikatard 440 (Hydration Controller) Sika Stabilizer 4R (Viscosity Modifier)	As Needed 1 – 3 2 – 8 1 – 7
Urban Mining	Sika Air 260 (Air Entrainer) Sika Visocrete 1000 (High-range Water Reducer) Sika Sikatard 440 (Hydration Controller) Sika Stabilizer 4R (Viscosity Modifier)	1.0 – 3.5 1.0 – 1.5 2 1
Terra CO2	Sika Air 260 (Air Entrainer) Sika Visocrete 1000 (High-range Water Reducer) Sika Sikatard 440 (Hydration Controller) Sika Stabilizer 4R (Viscosity Modifier)	1.6 – 1.7 2.2 – 2.5 2 1

Material	Admixture (Type)	Admixture Dosage fl oz per 100 lbs cement
Study Control	Sika Air 260 (Air Entrainer)	As Needed
	Sika Visocrete 1000 (High-range Water Reducer)	1 – 3
	Sika Sikatard 440 (Hydration Controller)	2 – 8
	Sika Stabilizer 4R (Viscosity Modifier)	1 – 7
Optimized Gradation	Sika Air 260 (Air Entrainer)	As Needed
	Sika Visocrete 1000 (High-range Water Reducer)	1 – 3
	Sika Sikatard 440 (Hydration Controller)	2 – 8
	Sika Stabilizer 4R (Viscosity Modifier)	0 – 7
Burgess Pigment	Sika Air 260 (Air Entrainer)	5.5 – 6.5
	Sika Visocrete 1000 (High-range Water Reducer)	3.5 – 4.2
	Sika Sikatard 440 (Hydration Controller)	2
	Sika Stabilizer 4R (Viscosity Modifier)	1
3M	Sika Air 260 (Air Entrainer)	1.6 – 2.0
	Sika Visocrete 1000 (High-range Water Reducer)	0.1 – 0.6
	Sika Sikatard 440 (Hydration Controller)	2
	Sika Stabilizer 4R (Viscosity Modifier)	1
Hess Pumice	Sika Air 260 (Air Entrainer)	2 – 3
	Sika Visocrete 1000 (High-range Water Reducer)	2 – 3
	Sika Sikatard 440 (Hydration Controller)	2
	Sika Stabilizer 4R (Viscosity Modifier)	1
Continental IL(20)	Sika Air 260 (Air Entrainer)	As Needed
	Sika Visocrete 1000 (High-range Water Reducer)	1 – 3
	Sika Sikatard 440 (Hydration Controller)	2 – 8
	Sika Stabilizer 4R (Viscosity Modifier)	1 – 7
Carbon Limit	Sika Air 260 (Air Entrainer)	1.5 – 2.0
	Sika Visocrete 1000 (High-range Water Reducer)	3.0 – 6.5
	Sika Sikatard 440 (Hydration Controller)	2
	Sika Stabilizer 4R (Viscosity Modifier)	1

[1] MBS = Master Builder Solutions
[2] Sika = Sika USA

A specific review of the materials placed in each cell is presented below.

CELL #2209 ULTRAHIGH MATERIALS

The UltraHigh Materials product was a hydraulic cement containing no Portland cement clinker, and no supplementary cementitious material (SCM) was added at the concrete plant. The binder formulation used at MnRoad included Class C fly ash as the major component and the primary binder with calcium carbonate (limestone powder) and calcium aluminate cement.

CELLS #2210, #2211, #2212, AND #2217 CARBONCURE™ EXPERIMENT

These 4 cells represent the calcium carbonate mineralization experiment, consisting of a control mix (Cell #2217), a control with 0.1% CO_2 by weight of cement (Cell #2211), a CarbonCure™ optimized mix with 0.1% CO_2

by weight of cement (Cell #2210), and the CarbonCure™ optimized mix without CO_2 added. It is noted that the AASHTO M 240 Type IL(10) cement (from the Continental Davenport plant) and aggregate used in these cells is different from what was used elsewhere in the study, as the concrete was supplied by the only local concrete producer equipped with the CarbonCure™ technology.

CELL #2213 CARBON UPCYCLING

Carbon Upcycling Technology (CUT) produces an ASCM using a patented process that grinds the feedstock material in a ball mill while subjecting it to a pressurized CO_2 environment. The grinding reduces particle size, improving reactivity, and exposes fresh surfaces of the feedstock which can carbonate in the pressurized CO_2 environment. According to the producer, several industrial byproducts or natural minerals can be used as feedstock. For MnROAD, the feedstock was harvested Class F fly ash. The CUT concrete mixture design reduced the total cementitious content from 570 pcy in the control mixture to 500 pcy (including their ASCM material at 30% replacement of total weight of cementitious materials) in the job mixture.

CELL #2214 ASH GROVE TYPE IP(30)

This cell was constructed using an AASHTO M 240 Type IP(30) produced by Ash Grove with Type I/II Portland cement blended with 30% AASHTO M 295 Class N calcined clay natural pozzolan. This product is sold as Duracem® N.

CELL #2215 URBAN MINING

This cell features Urban Mining's Pozzotive® ground glass pozzolan meeting ASTM C1866. This product is produced by finely grinding waste glass obtained from municipal waste. It was added at 30% replacement by total weight of cementitious materials.

CELL #2216 TERRA CO2

Terra CO2 is a synthetic ASCM manufactured by partially melting rock that has a bulk composition similar to AASHTO M 295 Class F fly ash and then rapidly cooling in an air stream to form spherical glass particles resembling fly ash in composition, structure, morphology, and particle size. It was added at 30% replacement by total weight of cementitious materials.

CELL #2218 EXPERIMENTAL CONTROL

This is a standard MnDOT concrete paving mixture featuring a typical total cementitious materials content of 570 pcy with a fly ash replacement level of 30% by weight of total cementitious materials.

CELL #2219 OPTIMIZED CONCRETE MIXTURE

This mixture used the same constituent materials the control (Cell #2218), but the aggregate grading was further optimized and the cementitious materials content reduced to 501 pcy with a fly ash replacement level of 30% by weight of total cementitious materials.

CELL #2220 BURGESS PIGMENT METAKAOLIN

This is a metakaolin natural pozzolan commercially available as Optipozz™ and produced by calcining high purity kaolin clay. Metakaolin has a high surface area and is highly reactive. It was added at 12% replacement by total weight of cementitious materials, with Coal Creek fly ash added at 18% by total weight of cementitious materials.

CELL #2221 3M NATURAL POZZOLAN

The 3M™ NP100W AASHTO M 295 Class N natural pozzolan was collected in a baghouse during production of shingle granules. It was provided as a blended product (50:50) with an AASHTO M 295 Class F fly ash from the Prairie State Plant in Illinois. The blend was added at 30% replacement by total weight of cementitious materials.

CELL #2222 HESS PUMICE

Hess Pumice is a finely ground, low-density pumice that is classified as an AASHTO M 295 Class N natural pozzolan. It was added at 30% replacement by total weight of cementitious materials.

CELL #2223 CONTINENTAL TYPE IL(20)

Continental Cement provided an off-specification Portland-limestone blended cement with a higher-than-permitted interground limestone content of 20% (15% is the maximum permitted in the AASHTO M 240 standards). Class F fly ash from Coal Creek was added at 30% replacement by total weight of cementitious materials.

CELL #2224 CARBON LIMIT

Carbon Limit is a proprietary blended ASCM composed largely of ground limestone and a natural pozzolan, with other proprietary natural materials. It is a non-calcined material that the manufacturer claims can sequester additional atmospheric carbon dioxide while in-service beyond what is typically absorbed by conventional concrete. It was added at 30% replacement by total weight of cementitious materials.

Chapter 3: Preliminary Assessment of ECC of Concrete Mixtures

The overarching goal of the MnROAD placements and the follow-up research is to evaluate the performance of low ECC concrete materials/technologies. To that end, the ECC of each must be verified, to the degree possible, and compared to traditional concrete paving mixtures. These will be compared in greater detail as part of follow-up research projects, but a preliminary assessment is provided here. There was at the beginning of the project, and remains, a lack of specific environmental data for many of the materials being evaluated in this study. Therefore, only a qualitative assessment of the ECC for each concrete has been made and compared to the control mixture at this time. The premise for this qualitative assessment is:

- Portland cement clinker production is responsible for as much as 90%[3] of the ECC of concrete at the gate of the ready mixed concrete plant. Reducing clinker content will result in a corresponding reduction in ECC, all other factors being equal.

- Some SCMs derived directly from waste, such as fresh fly ash, have only the ECC due to loading and transportation attributed to them. Other SCMs, such as natural pozzolans and harvested fly ash will have higher ECC than fresh fly ash due to required processing. Calcined clay, slag cement, and manufactured SCMs will require additional processing operations and will therefore have even higher ECC than the already identified SCMs.

- Concrete made using less cementitious content than the control mixture (i.e., significant clinker replacement with a lower ECC SCM) would have a reduced ECC directly proportional to the reduction in cementitious content.

This chapter includes a discussion on environmental product declarations (EPDs) for the control mixture relative to industry-wide environmental impact averages for ready mixed concrete. The limiting factor in comparing the control mixture to many of the other mixtures is the lack of available EPDs for many of the products used in this study. Therefore, only a preliminary discussion on the environmental impact of the materials is presented, with the intent that environmental impact data will be available in the future for these products, allowing for a more definitive assessment.

3.1 Environmental Product Declarations

A Type III EPD is a transparent and verified report that states the environmental impact of any product, including construction materials. EPDs are developed in accordance with International Organization for Standardization (ISO) Standard 14025, which incorporates a critical review process to make sure that rules set forth in the

[3] Choate, W. 2003. *Energy and Emissions Reduction Opportunities for the Cement Industry.* Prepared for the Industrial Technologies Program, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. December 29.

Product Category Rule (PCR) document were followed. Development of a PCR is at the request of stakeholders and facilitated by a program operator. The PCR is verified by a third-party independent review panel, who ensures the PCR is compliant with ISO 14025 and any other relevant standards. To publish an EPD, a life cycle assessment (LCA) is developed following the pertinent instructions for the product(s) specified in the PCR. The EPD uses the results of the LCA with defined content and format to state the environmental impact of the product. After a neutral third-party program operator has verified the EPD is compliant with the PCR, the EPD will be issued. EPDs are developed for the stages of product life cycle for which information is available. These life cycle stages are referred to as cradle-to-gate (EN 15084 modules A1 – A3), cradle-to-site (EN 15804 modules A1 – A5), or cradle-to-grave (EN modules A1 – A5, B1 – B7, and C1 – C4). The A1 – C4 designations are illustrated in Figure 1.

3.2 EPD of the Control Mixture

The EPD for the control mixture in this study was provided by Aggregate Industries for their Maple Grove Ready Mix Concrete Plant in Maple Grove, MN. The EPD is a cradle-to-gate EPD covering only the production stage (A1 – A3). The environmental impacts for the control mixture are summarized in Figure 2. The Embodied Carbon in Construction Calculator (EC3) Tool[4] was used to compare the global warming potential of the control mixture with other ready mixed concrete mixtures with similar 28-day compressive strengths (Figure 3). Within the EC3 Tool, over 21,400 product EPDs were available nationally for ready mixed concrete comparable to the control mixture. The box plot shows the typical range that 60% of the known products in that category fall within, with 313 $kgCO_2eq/m^3$ (239 $kgCO_2eq/yd^3$) considered an “achievable” value and 460 $kgCO_2eq/m^3$ (352 $kgCO_2eq/yd^3$) being a conservative estimate[5].

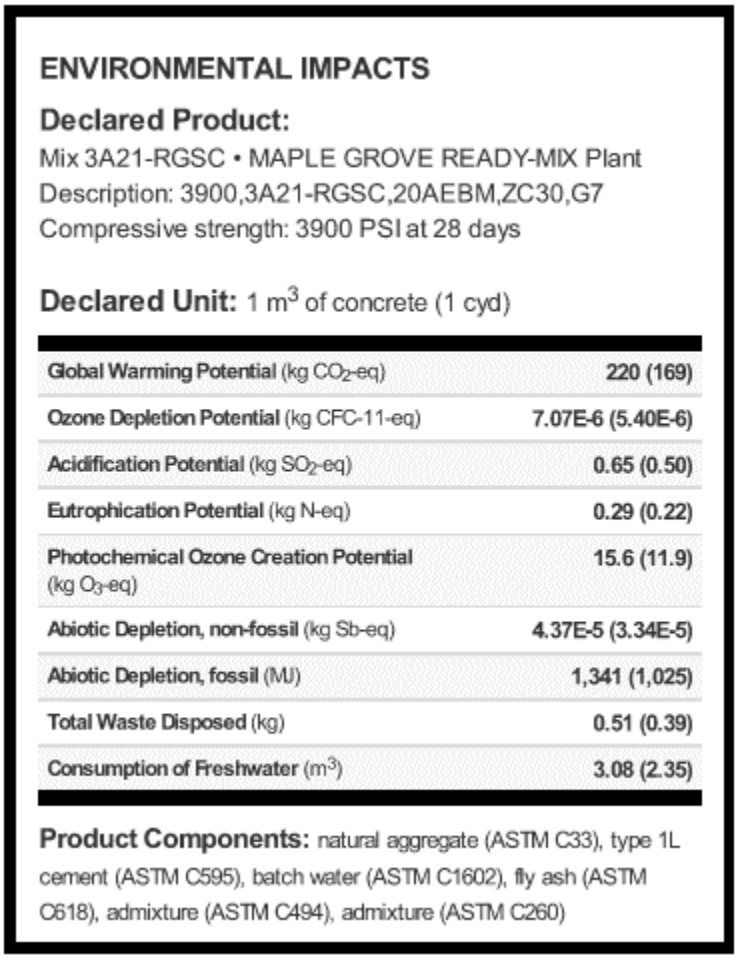
[4] Free use software available at https://www.buildingtransparency.org/.

[5] Note that reporting ECC is commonly done in metric units. Although the unit of volume has been converted from metric to English (m^3 to yd^3) in the EPD, the unit of mass remains in $KgCO_2eq$, consistent with industry and international practice).

EN 15804 Module	Life Cycle Stage	Process	EN 15804 Module #	Cradle-to-Gate EPD	Cradle-to-Gate EPD with options	Cradle-to-Site EPD	Cradle-to-Grave EPD
EN 15804 Module A	Product Stage 	Raw Material Supply	A1	X	X	X	X
		Transport	A2	X	X	X	X
		Manufacturing	A3	X	X	X	X
	Construction Process Stage 	Transport	A4	-	O	X	X
		Construction	A5	-	O	X	X
EN 15804 Module B	Use Stage 	Use	B1	-	O	-	X
		Maintenance	B2	-	O	-	X
		Repair	B3	-	O	-	X
		Replacement	B4	-	O	-	X
		Refurbishment	B5	-	O	-	X
		Operational energy use	B6	-	O	-	X
		Operational water use	B7	-	O	-	X
EN 15804 Module C	End-of-Life Stage 	Demolition	C1	-	O	-	X
		Transport	C2	-	O	-	X
		Wastage processing	C3	-	O	-	X
		Disposal	C4	-	O	-	X

X = Mandatory O = Optional - = n/a

Figure 1. Life-cycle stages included in EPDs applied to pavement LCA (FHWA-HIF-19-087)



ENVIRONMENTAL IMPACTS

Declared Product:

Mix 3A21-RGSC • MAPLE GROVE READY-MIX Plant
Description: 3900,3A21-RGSC,20AEBM,ZC30,G7
Compressive strength: 3900 PSI at 28 days

Declared Unit: 1 m^3 of concrete (1 cyd)

Global Warming Potential (kg CO_2-eq)	**220 (169)**
Ozone Depletion Potential (kg CFC-11-eq)	**7.07E-6 (5.40E-6)**
Acidification Potential (kg SO_2-eq)	**0.65 (0.50)**
Eutrophication Potential (kg N-eq)	**0.29 (0.22)**
Photochemical Ozone Creation Potential (kg O_3-eq)	**15.6 (11.9)**
Abiotic Depletion, non-fossil (kg Sb-eq)	**4.37E-5 (3.34E-5)**
Abiotic Depletion, fossil (MJ)	**1,341 (1,025)**
Total Waste Disposed (kg)	**0.51 (0.39)**
Consumption of Freshwater (m^3)	**3.08 (2.35)**

Product Components: natural aggregate (ASTM C33), type 1L cement (ASTM C595), batch water (ASTM C1602), fly ash (ASTM C618), admixture (ASTM C494), admixture (ASTM C260)

Figure 2. EPD for 1 cubic meter of the control mixture (from EPD produced by Climate Earth for Aggregate Industries)

The baseline established by the Carbon Leadership Forum (CLF) represents a high estimate for embodied carbon for that product if no effort is made to choose a low-carbon alternative. For this product category, the 2021 CLF Baseline is 470 $kgCO_2eq/m^3$ (359 $kgCO_2eq/yd^3$). The average embodied carbon for ready mix concrete that is comparable to the control mixture in terms of strength is 386 $kgCO_2eq/m^3$ (295 $kgCO_2eq/yd^3$). Based on the EPD from Aggregate Industries, the embodied carbon for the control mixture at 220 $kgCO_2eq/m^3$ (169 $kgCO_2eq/yd^3$) falls well below that average and is also below the “achievable” value from the EC3 Tool.

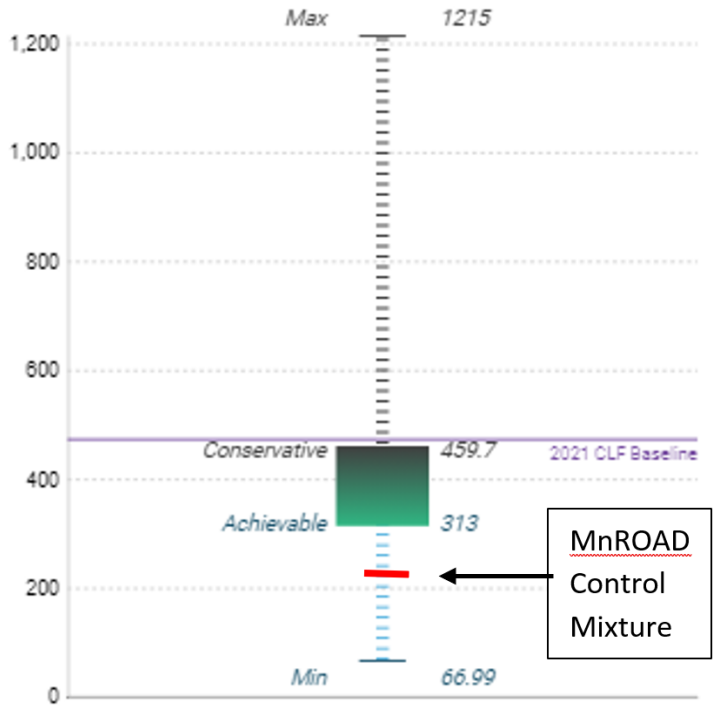


Figure 3. Embodied carbon for 1 cubic meter of ready-mix concrete for 28-day compressive strength of approximately 3900 psi from the EC3 Tool. MnROAD control embodied carbon added for comparison

3.3 Comparison of Mixtures

EPDs are not currently available for many of the materials used in this study. The development of a PCR is on-going for some of these materials, such as the natural pozzolans. For other materials, ISO 21930, which is the core PCR for construction products and services, would need to be used to develop an EPD. Therefore, the ability to quantitatively assess the ECC of these materials is presently limited. The research team has sent a request to each material supplier as part of the continuing studies to develop a deeper understanding of the constituent materials, and how they are mined, processed, and transported. This information will be used in the future to better quantify their respective ECC and provide a basis for EPD development.

The global warming potential (GWP) for common cementitious materials used on this project have been obtained from available data and EPDs (Table 5). Note the GWP of the Holcim cement used for most of the test cells at MnROAD is roughly 5% lower than the national average. Also, the GWP of Class F fly ash is, on average, less than 2% of that of Portland cement.

Table 5. GWP for common cementitious materials and source of information

Material	GWP ($kgCO_2$-eq/mt)	Source
Average Cement (U.S.)	922	EPD for the Portland Cement Association (PCA) (3/12/21)
Holcim Ste. Genevieve AASHTO M 85 Type I/II	748	EPD for Ste. Genevieve, MO Cement Plant (2/26/2021)
Holcim St. Genevieve AASHTO M 240 Type IL(8)[1]	724	EPD for Ste. Genevieve, MO Cement Plant (2/26/2021)
Class F fly ash	12.1	FHWA LCAPave Tool
Carbon Upcycling CUT ASCM	221	Carbon Upcycling Screening LCA (5/25/2023)
Urban Mining Pozzotive® ground glass pozzolan	55.9	EPD for Urban Mining Pozzotive® ground glass pozzolan (5/11/20)

[1] Holcim Ste. Genevieve Type IL(8) was the base cement used in the study. The calcium carbonate mineralization test cells (Cells #2210, #2212, #2213, and #2217) used Continental Davenport Type IL(10). Continental Cement also provided the Type IL(20) used in test cell #2223. The source of the clinker used in the Ash Grove Type IP(30) is not known.

Although the available environmental data on the specific products used at MnROAD is limited, it is known that Portland cement is responsible for almost 90% of the ECC of a typical concrete mixture at the plant gate. Thus, a preliminary qualitative assessment can be made to compare the ECC of the mixtures based on 1) the cementitious binder content in the concrete, and 2) the equivalent percentage of the binder that is Portland cement. The latter is determined by dividing the total cementitious binder content as summarized in Table 6.

For a given cementitious materials blend, the lower the cementitious content, the lower the carbon footprint of the concrete mixture. The control mixture used a blend of Type IL(8) cement with a 30% replacement with Class F fly ash, having a total cementitious content of 570 pcy. The Optimized Gradation mixture used the same cementitious materials in the same proportions, but only had 501 pcy of total cementitious content, resulting in a sizable reduction in the ECC. Three other mixtures had a cementitious content below the control: the Carbon Upcycling mixture (500 pcy) and the 2 CarbonCure™ mixtures (558 pcy).

The highest Portland cement replacement level was for the Continental Cement mixture with Type IL(20) and 30% Class F fly ash. This corresponds to a nominal 56% Portland cement in the binder. This was followed by the Terra CO2 mixture at 60% Portland cement.

Table 6 also shows that the UltraHigh Materials mixture has the highest cementitious content at 650 pcy. However, as there was no Portland cement clinker in the binder and the Class C fly ash and ground limestone have a very low ECC, this results in a very low equivalent Portland cement in the binder.

Table 6. Clinker replacement comparison

Material	Cementitious Content	Cement Type	Cement Replacement	Portland Cement in Binder (pcy)
UltraHigh	650 pcy	Hydraulic cement	No Portland cement clinker in the cement	0[1]
CarbonCure w/CO_2	558 pcy	Type IL(10)	30% fly ash	352
CarbonCure Control w/CO_2	570 pcy	Type IL(10)	30% fly ash	359
CarbonCure wo/CO_2	558 pcy	Type IL(10)	30% fly ash	352
Carbon Upcycling	500 pcy	Type IL(8)	30% treated ash	322
Ash Grove IP(30)	570 pcy	Type IP(30)	30% calcined clay	399
Urban Mining	570 pcy	Type IL(8)	30% ground glass pozzolan	367
Terra CO2	570 pcy	Type IL(8)	35% Terra CO2 SCM	341
CarbonCure Control wo/CO_2	570 pcy	Type IL(10)	30% fly ash	359
Control	570 pcy	Type IL(8)	30% fly ash	367
Optimized Gradation	501 pcy	Type IL(8)	30% fly ash	323
Burgess Pigment	570 pcy	Type IL(8)	12% pozzolan, 18% fly ash	367
3M	570 pcy	Type IL(8)	15% 3M pozzolan, 15% fly ash	367
Hess Pumice	570 pcy	Type IL(8)	30% pumice pozzolan	367
Continental IL(20)	570 pcy	Type IL(20)	30% fly ash	319
Carbon Limit	570 pcy	Type IL(8)	30% limestone-pozzolan blend	367

[1] The binder formulation included Class C fly ash as the major component and primary binder, calcium carbonate (limestone powder), and calcium aluminate cement.

Using this information, a qualitative comparison was made using the control mixture as the standard, with the results presented in Table 7. The first step was to determine the estimated Portland cement content in each mixture by multiplying the total cementitious content by the percent Portland cement equivalent presented in Table 6. For comparison, the control mixture has 367 pcy Portland cement, which is the total cementitious content multiplied by 0.92 to subtract the 8% limestone in the Type IL(8) and then multiplying by 0.70 to account for the 30% fly ash. Table 7 discusses the relative GWP rating per material.

Table 7. Relative ECC materials cradle-to-gate comparison[6]

Material	Portland Cement Content	GWP from Cement	GWP from SCM	Overall GWP Rating	Notes
UltraHigh	0	0	⇓⇓	⇓⇓	The UltraHigh Materials hydraulic cement is primarily fly ash, with ground limestone and calcium aluminate cement as minor components. It would be expected to have a low ECC.
CarbonCure w/CO_2	352 pcy[1]	⇔	⇔	⇔	The slight reduction in total cementitious materials content resulted in a slightly lower ECC. The impact on the GWP of the injected CO_2 is considered minimal.
CarbonCure Control w/CO_2	359 pcy[1]	⇔	⇔	⇔	Little change in the ECC from the control. The impact on GWP of the injected CO_2 is considered minimal.
CarbonCure wo/CO_2	352 pcy[1]	⇔	⇔	⇔	The slight reduction in total cementitious materials content will result in a slightly lower ECC.
Carbon Upcycling	322 pcy	⇓⇓	⇑⇑	⇔	The Carbon Upcycling mixture has the second lowest Portland cement content. Yet the ASCM has an ECC 18 times higher than fly ash based on its screening LCA. These two offset each other and little reduction in overall ECC occurs.
Ash Grove IP(30)	399 pcy	⇑	⇑⇑	⇑⇑	The Ash Grove Type IP(30) mixture would likely have the highest ECC of any mixture used. The base cement (Type I/II) has a higher clinker content than the Type IL(8) and the calcined clay natural pozzolan has a higher GWP than fly ash due to the heat required for calcination and grinding.
Urban Mining	367 pcy	⇔	⇑	⇑	The Urban Mining ground glass pozzolan mixture will have a slightly higher ECC than the control due to processing and grinding.
Terra CO2	341 pcy	⇓	⇑	⇔	The Terra CO2 mixture has a reduced Portland cement content but a higher ECC for the ASCM due to production. These likely offset each other, resulting in little impact on the ECC of the mixture.

[6] Note that transportation is not included in this analysis.

Material	Portland Cement Content	GWP from Cement	GWP from SCM	Overall GWP Rating	Notes
CarbonCure Control wo/CO_2	359 pcy[1]	⇔	⇔	⇔	Little change in the ECC from the control.
Control	367 pcy	Control	NA	NA	NA
Optimized Gradation	323 pcy	⇓⇓	⇔	⇓⇓	The optimized concrete mixture has a low Portland cement content and thus a lower ECC than the control.
Burgess Pigment	367 pcy	⇔	⇑	⇑	The Burgess metakaolin has increased GWP due to the heat required for calcination and grinding. This would be expected to slightly increase the ECC above the control.
3M	367 pcy	⇔	⇔	⇔	No change in the ECC from the control is expected as the 3M Class N natural pozzolan is utilized waste material.
Hess Pumice	367 pcy	⇔	⇑	⇔	The Hess ground pumice has a slightly increased GWP due to the grinding. This would be expected to slightly increase the ECC above the control.
Continental IL(20)	319 pcy	⇓⇓	⇔	⇓⇓	The Continental Type IL(20) coupled with a 30% replacement with fly ash resulted in a low Portland cement content and a lower ECC than the control.
Carbon Limit	367 pcy	⇔	⇔	⇔	No change in the ECC from the control. It is assumed that the additional GWP incurred due to processing the Carbon Limit ASCM is offset by the CO_2 sequestered in service.

[1] The Continental Davenport Type IL(10) has slightly more ground limestone than the Holcim Ste. Genevieve Type IL(8) and therefore mixtures with the same Portland cement content will have a slightly lower Portland cement clinker content. An EPD was not available for the Continental Davenport Type IL(10), so it was assumed to have a similar ECC to the Holcim Ste. Genevieve Type IL(8).

The GWP from the Portland cement content alone was then rated as follows:

- ⇔ – Within 5% of the Portland cement content of the control (349 – 385 pcy).
- ⇓ – Between 5 and 10% less 18 Portland cement than the control (330 – 349 pcy).
- ⇓⇓ – More than 10% less Portland cement than the control (< 330 pcy).
- ⇑ – Greater than 5% more Portland cement than the control (> 385 pcy).

The SCM GWP rating was qualitatively determined by comparing the SCM(s) or ASCM used to the Class F fly ash used in the control. The GWP from the SCM content was then rated as follows:

- ⇔ – No impact relative to the conventional fly ash that was used. This would be the case if the same fly ash was used, or another fly ash or material with offsetting influences resulting in net zero GWP difference was used.

- ⇑ – A small increase in the GWP is anticipated due to nominal processing (i.e., grinding) of the SCM beyond what is done with conventional fly ash or when more rigorous processing (i.e., heating and grinding) is offset by enhanced carbonation.

- ⇑⇑ – A large increase in GWP is anticipated due to rigorous processing (i.e., heating and grinding) without offsets such as enhanced carbonation.

The overall GWP rating was qualitatively determined by considering the combined GWP ratings for the cement and SCM. Notes are used to clarify the rationale for each rating. The overall qualitative GWP was then rated as follows:

- ⇔ – No impact on the overall mixture GWP relative to the control mixture.

- ⇓ – Small decrease in the overall mixture GWP relative to the control mixture.

- ⇓⇓ – Large decrease in the overall mixture GWP relative to the control mixture.

- ⇑ – Small increase in overall mixture GWP relative to the control mixture, often due to slight processing of the SCM.

- ⇑⇑ – Greater increase in overall mixture GWP relative to the control mixture often due to more intensive processing of the SCM.

Due to a lack of quantitative data, this environmental analysis is purely qualitative and based on the limited information available at this time. These results will become more defined as better information is provided. Some materials/strategies that resulted in significant carbon reduction included:

- Reducing the total cementitious content (Carbon Upcycling and Optimized Gradation).

- Reducing the Portland cement clinker content through replacement with low ECC alternative materials such as ground limestone and SCMs (UltraHigh Materials and Continental 1L(20)).

Chapter 4: Construction QA Testing Plan

The recommended 3-part construction QA testing plan was based on the criteria established at the mixture design stage. The first part was a plan for MnDOT inspection of the concrete plant during production. It included a checklist that verified that plant certification and all calibrations were up to date. Aggregate stockpiles were inspected for moisture content and segregation, cementitious materials and admixtures were verified, and general plant operations were observed. The second part was a typical sampling and testing plan for samples taken during construction to ensure that the concrete as delivered met mixture requirements. The third part was the collection of additional concrete samples from the production concrete. The complete testing matrix is shown in Table 8.

Given the large number of samples and limited time, multiple personnel prepared and tested samples. Representatives from American Engineering Testing (AET), FHWA Mobile Concrete Lab (MCTC), and Iowa State University were all on site and either casting samples or running fresh properties tests.

Additional tests are still being performed on these mixtures and materials, including:

- Quantifying carbon sequestration analysis. This is being conducted by the National Institute for Standards and Technology and the FHWA Turner Fairbank Highway Research Center.
- Carbon uptake and thermal gravimetric analysis. This is being conducted by Iowa State.
- Chemical composition and chemical analysis.
- Pore solution expression, pH, and electrical resistivity analysis.

At the time of this report, not all construction-day testing had been completed. Preliminary results from AET are reported in Section 5. The MCTC data will be available electronically as it is finalized. A complete list of all tests being performed is included in Appendix B.

Table 8. Construction quality assurance concrete test matrix

Property	Test Method	Test Frequency
MnDOT Aggregate Quality Tests	MnDOT 3126, 3131, 3137	1 per fraction per plant per week
Paste Content and Gradation	PP84	1 per fraction per plant per week
Air Content	C231/T152	1 per 50 cy
SAM	TP118	1 per 100 cy
Hardened Air Content	C457	1 per cell
Unit Weight	C138	1 per 50 cy
Slump	T119	1 per 50 cy
Temperature	C1064	1 per 50 cy
Box Text	PP84	1 per cell
V-Kelly	PP84	1 per cell
Phoenix	T152	1 per cell
Microwave	T318	1 per cell
Compressive Strength (1-, 3-, 7-, 14-, 28-, 42-, and 56-day)	C39	1 per 50 cy
Flexural Strength (3-, 7-, 14-, 28-, and 56-day)	C78	1 per cell
Maturity	C1074	N/A
Resistivity (1-, 3-, 7-, 14-, 28-, 42-, and 56-day)	T358	Test compressive cylinders
Rapid Chloride Permeability (56-day)	C1202	2 per cell
Bulk Resistivity (7-, 28-, 56-, 91-, and 120-day)	C1876-19	6 per cell

Property	Test Method	Test Frequency
Freeze-Thaw Resistance	C666	1 per cell
Time to Critical Saturation	PP84	1 per cell
Deicing Salt Damage	T365	1 per cell
ASR-Concrete Prism	C1293	1 per cell
ASR-Miniature Concrete Prism	T380	1 per cell
Mortar Bar Expansion	C1567	1 per cell
Mortar Bar	C1260	For Continental Cement Cell Only
Poisson's Ratio and Elastic Modulus	C469	1 per cell
Coefficient of Thermal Expansion	T336	1 per cell
Drying Shrinkage (35-day)	C157	1 per cell
Expansion of Mortar Bars stored in water	C1038	1 per cell
Expansion of Mortar Bars in Sulfate Solution (1-year)	C1012	1 per cell
Fly Ash or Natural Pozzolan Classification	C311	1 per cell
Semi-Adiabatic Calorimetry	C1679	1 per cell

Chapter 5: Construction Support

Construction of the 16 test cells occurred between July 27 and August 9, 2023. A member of the project team, Dr. Larry Sutter, was available on-site for consultation during the construction phase to assist in coordinating the construction of the test cells and to address issues that may have arisen.

Dr. Sutter also was on-site to make general observations on the constructability of each test cell. Each material was proportioned in the laboratory to have acceptable fresh and hardened concrete properties. The main element of this study was to demonstrate that laboratory performance could translate into the field, and that in the case of alternative materials, mixtures could be consistently produced with sufficient workability for placement and consolidation and could be finished and cured without major difficulties. To assess this, each phase of the material's journey, from arrival at the batch plant to joint sawing and curing, was qualitatively rated based on its suitability for large scale paving. These ratings are summarized in Table 9 (mixing/transportation), Table 10 (placement/consolidation), Table 11 (finishing/curing), and Table 12 (joint sawing)[7]. Select photos from construction are provided in Appendix C.

5.1 Material Handling, Mixing, and Transportation

The first step in construction was the delivery of the raw materials to the batch plant. Most alternative cementitious and alternative pozzolanic materials were delivered to MnROAD in super sacks or directly to the plant by pneumatic tanker. Delivery by super sacks was not preferred; it took considerable time to transfer material from super sacks into a pneumatic tanker and then the silo at the ready mixed plant.

The concrete was batched and mixed at a central plant and discharged into ready mixed concrete trucks for delivery. The materials had good batch-to-batch uniformity, with a few exceptions:

- The Burgess Pigment mixture (Cell #2220) was very dry, with 1-inch clumps of dry material in the mix. Additional water did not appear to improve workability. This was due to the inability to uniformly disperse the metakaolin, which was shipped in 50 lb bags and was added separately to the truck after all other materials were batched. The plant experimented with adding the metakaolin before the other ingredients and after. Adding it prior to mixing with the other raw materials seemed to work slightly better than adding it after mixing. Significant quantities of water were added in transit and the mixture design was adjusted over the batching period to significantly increase the water reducer dosage.
- The Carbon Limit mixture (Cell #2224) was dry, had color variations (i.e., streaking) behind the paver, and had an extremely high water demand. Poor mixing of the material was noted, with color variation in

[7] No construction observations were recorded for the UltraHigh Materials (Cell #2209) due to early setting issues.

the fresh concrete. The material was delivered unblended in super sacks and therefore a uniform blend was not achieved in batching.

- The Terra CO2 mixture (Cell #2216) required approximately 3 minutes of mixing at the batch plant before discharge into the concrete delivery trucks.

5.2 Workability, Placement, and Consolidation

Once the concrete was delivered to the job site, its workability, placement, and consolidation were evaluated. The workability was acceptable for most mixes. The Urban Mining (Cell #2215), Burgess Pigment (Cell #2220), 3M (Cell #2221), and Carbon Limit (Cell #2224) mixtures all required additional water or additional water reducer to achieve the desired workability at placement. There were concerns with early setting with the Ash Grove (Cell #2214) and Carbon Limit (Cell #2224) mixtures, requiring them to be placed quickly before becoming too stiff to consolidate. There were noticeable tears in the control with CarbonCure (Cell #2211) mixture directly behind the paver that required some effort by the finishing crew to repair. The CarbonCure without CO_2 injection mixture (Cell #2212) had pronounced surface tears and issues with consolidation both on the surface and along the edges.

Table 9. Material handling, mixing, and transportation ratings

Material	Transportation to batch plant	Special storage and handling	Mixing procedure	Max time between batch deliveries to the field	Batch to batch variability	Mixing issues
UltraHigh Materials	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded
Ash Grove Type IP(30)	Pneumatic tanker	None	Central mix	30 minutes. Batched in Maple Grove, 2.5-hour delay in paving, cold joint was used	Good	None
Terra CO2	Super sacks loaded into pneumatic tanker	Loading super sacks took about 5 hours	Central mix	30 minutes	Good	Required 3 minutes of mixing at plant
Continental Cement Type IL(20)	Pneumatic tanker	None	Central mix	30 minutes	Good	None
CarbonCure With CO_2	N/A	N/A	Central mix	30 minutes	Good	None
Control With CarbonCure	N/A	N/A	Central mix	30 minutes	Good	None
CarbonCure Without CO_2	N/A	N/A	Central mix	30 minutes	Good	None
Carbon Upcycling	Pneumatic tanker	None	Central mix	30 minutes. Batched in Maple Grove	Good	Water reducing admixture (WR) held back on first load and was dry, adding remaining WR and mix was consistent
Urban Mining	Super sacks loaded into pneumatic tanker	Loading super sacks took about 4 hours, glass would not flow out of bags	Central mix	30 minutes	Good	Plant withheld VMA and retarder in first 3-4 loads. Mixtures were too stiff to place. Added

Material	Transportation to batch plant	Special storage and handling	Mixing procedure	Max time between batch deliveries to the field	Batch to batch variability	Mixing issues
						admixtures but then plant broke down. 80 yards were removed.
Optimized	N/A	N/A	Central mix	15 minutes	Good	None
Burgess Pigment	50 lbs sacks	Sacks manually emptied into mixer	Central mix	30 minutes	Poor	1-inch clumps of dry material, mix was very dry, additional water was needed in transit
3M	Pneumatic Tanker	None	Central mix	15 minutes	Good	None
Hess Pumice	Super sacks loaded into pneumatic tanker	None	Central mix	30 minutes	Good	None
Carbon Limit	Super sacks loaded into pneumatic tanker	Material received unblended, distinct layers of component powders	Central mix	30 minutes	Poor	Noticeable color variation behind paver, extreme water demand, very stiff mix

Table 10. Material workability, placement, and consolidation ratings

Material	Delivery	Workability	Early Setting	Placement	Consolidation	Mix Issues
UltraHigh Materials	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded
Ash Grove Type IP(30)	Concrete mixer truck	Good	Not a concern, but set faster than conventional mixture	Good	Good	None
Terra CO2	Concrete mixer truck	Good	None	Good	Good	None
Continental Cement Type IL(20)	Concrete mixer truck	Good	Yes, set quick after placement	Good	Good	Needed extra water to achieve desired workability
CarbonCure With CO_2	Concrete mixer truck	N/A	None	Good	N/A	None
Control With CarbonCure	Concrete mixer truck	Mix seemed stiff behind paver, noticeable tears that needed floating	None	Good	Good	None
CarbonCure Without CO_2	Concrete mixer truck	Good	Some mixes were stiff due to late delivery	Pronounced tearing on the surface, deep voids	Edges had poor consolidation	None
Carbon Upcycling	Concrete mixer truck	Good	None	Good	Good	None
Urban Mining	Concrete mixer truck	1st placement was unworkable due to admixture omission, 2nd placement much better	1st placement did, 2nd did not	1st placement nearly impossible, 2nd was good	1st placement was poor, 2nd was good	1st placement was never dialed in, 2nd was much better
Optimized	Concrete mixer truck	Good	None	Good	Good	None
Burgess Pigment	Concrete mixer truck	First few loads were dry, added water in transit and increased water reducer to later batches	None	Required lots of water and WR	Good	No signs of clumps in the finished concrete. A lot of water was added to truck

Material	Delivery	Workability	Early Setting	Placement	Consolidation	Mix Issues
3M	Concrete mixer truck	First few loads were wet, removed 0.5 gallon water and mix was good	None	Good	More pronounced bleed water compared to most other mixes	None
Hess Pumice	Concrete mixer truck	Good	None	Good	More pronounced bleed water compared to most other mixes	None
Carbon Limit	Concrete mixer truck	First few loads were dry, added water in transit and increased water reducer to later batches	Yes, set quickly after placement	Required lots of water and WR	Fair	A lot of water was added to truck

Table 11. Material finishing and curing ratings

Material	Finishing	Surface Texture	Curing	Weather Impacts
UltraHigh Materials	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded	No Construction Observations Recorded
Ash Grove Type IP(30)	Manual floats followed by Astroturf drag	Good, finishers said it was more difficult to finish, felt “gritty”	Curing compound	None
Terra CO2	Manual floats followed by Astroturf drag	Good, felt difficult to finish but not overly so	Curing compound	None
Continental Cement Type IL(20)	Manual floats followed by Astroturf drag	Good, surface stiffened quickly	Curing compound	None
CarbonCure With CO2	Manual floats followed by Astroturf drag	Adequate texture	Curing compound	None
Control With CarbonCure	Manual floats followed by Astroturf drag	Adequate texture	Curing compound	None
CarbonCure Without CO2	Manual floats followed by Astroturf drag	Adequate texture	Curing compound	None
Carbon Upcycling	Manual floats followed by Astroturf drag	Very good, some mortar clumps after dragging	Curing compound	None
Urban Mining	Manual floats followed by Astroturf drag	1st placement was torn surface, 2nd was good	Curing compound	None
Optimized	Manual floats followed by Astroturf drag	Good	Curing compound	None
Burgess Pigment	Manual floats followed by Astroturf drag	Good	Curing compound	None
3M	Manual floats followed by Astroturf drag	Good	Curing compound	None
Hess Pumice	Manual floats followed by Astroturf drag	Good	Curing compound	None
Carbon Limit	Manual floats followed by Astroturf drag	Poor, surface was torn, no texture, likely needs grinding	Curing compound	None

5.3 Finishing and Curing

All materials were finished in the same manner with manual floating and a specialized Astroturf carpet drag. Good surface texture was obtained on some cells; however, most cells were subsequently diamond ground, as surface texture was inadequate. The Carbon Limit mixture (Cell #2224) had no texture, and grinding was needed to achieve sufficient skid resistance. The finishers recorded some observations:

- Ash Grove Type IP(30) mixture (Cell #2214) felt "gritty" and was difficult to finish.
- Terra CO2 mixture (Cell #2216) was difficult to finish.
- Continental Cement Type IL(20) mixture (Cell #2223) stiffened quickly and there was little time to finish without adding additional water to the surface.

5.4 Joint Sawing

Joints were sawed approximately 4 – 6 hours after placement. Only the Carbon Limit mixture (Cell #2224) had any joint sawing issues. The saw operators reported that the surface hardened but the underlying concrete was poorly cured and did not set up as quickly as traditional concrete mixtures.

5.5 Overall Constructability Assessment

The construction of the cells at the MnRoad facility provided insight into the suitability of each material's ability to be used in large-scale paving operations. As some of these materials had never been batched in large quantities, growing pains were to be expected. There were some observations worth further discussion:

- Delivery of the cementitious materials in super sacks is not ideal. While the materials were ultimately transferred into silos via pneumatic pump trucks, it took many people up to 5 hours to transfer the materials. Having these materials arrive at the batch plant in pneumatic trucks would be necessary to sustain a multi-day paving job.
- Most materials had a much higher water demand than originally anticipated. Additional mixing water and higher dosages of water reducing admixtures were necessary to achieve a workable material.
- Future demonstration projects should include trial batching and placement at the ready mixed plant after trail batching in the laboratory, to ensure mixture design scales up to the ready mixed plant.

Despite some minor challenges, all but 1 of the mixtures was able to be constructed. For the 1 mixture that was not constructed, it is believed that with more time in the trial batching process, a constructable mixture could be developed.

Table 12. Material joint sawing ratings

Material	Timing of joint sawing after placement	Joint sawing issues
UltraHigh Materials	No Construction Observations Recorded	No Construction Observations Recorded
Ash Grove Type IP(30)	4 – 6 hours	None
Terra CO2	4 – 6 hours	None
Continental Cement Type IL (20)	4 – 6 hours	None
CarbonCure With CO2	4 – 6 hours	None
Control With CarbonCure	4 – 6 hours	None
CarbonCure Without CO2	4 – 6 hours	None
Carbon Upcycling	4 – 6 hours	None
Urban Mining	4 – 6 hours	None
Optimized	4 – 6 hours	None
Burgess Pigment	4 – 6 hours	None
3M	4 – 6 hours	None
Hess Pumice	4 – 6 hours	None
Carbon Limit	4 – 6 hours	Raveling, saw operators reported hard surface and poorly cured sub-surface

Chapter 6: Preliminary Material Test Results

Material testing is ongoing, and not all tests have been completed at the time of this report. The average values of all test results collected by AET as part of construction quality assurance testing are presented below.

6.1 Fresh Properties

The fresh properties measured included slump, air content, SAM number, unit weight, temperature at delivery, box test, and edge slump. The results are summarized in Table 13. In general, all mixtures had similar temperature, unit weight, and edge slump results. The edge slumps ranged from 0.6 in. for the UltraHigh Materials mixture (Cell #2209) and the Carbon Limit mixture (Cell #2224) to 4.3 in. for the Burgess Pigments mixture (Cell #2220). The target air content was between 5% and 8%. Only the Carbon Upcycling mixture (Cell #2213) tested below the minimum value at 4.9%, while the Burgess Pigment (8.7%) and UltraHigh Materials (9.3%) mixtures tested above the maximum value. The box test results did not identify any potential placement issues except for the CarbonCure without CO_2 injection (Cell #2212) and UltraHigh Materials (Cell #2209) mixtures, which both had sizable voids along the formed edges.

6.2 Hardened Air Content

The results of the hardened air test are summarized in Table 14 and plotted in Figure 4. The results show that the air contents of the mixtures are, on average, lower than the air contents of fresh concrete. Three mixtures had less than the 5% minimum air content and 1 cell had greater than the 8% maximum air content. All mixtures had no edge slump.

Table 13. Summary of fresh properties

Material (Cell #)	Slump (in)	Air Content (%)	SAM Number	Unit Weight (lb/ft^3)	Concrete Delivery Temperature (°F)	Average Box Test Rating
Study Control (2218)	2.6	6.7	0.075	145.0	74.0	1.3
Optimized (2219)	1.3	6.9	0.085	146.3	79.0	1.0
CarbonCure Control w/CO_2 (2211)	1.8	6.6	0.205	146.7	79.0	1.0
CarbonCure Control wo/CO2 (2217)	2.3	6.1	0.220	146.2	79.0	1.0
CarbonCure wo/CO2 (2212)	1.4	6.1	0.255	146.7	79.7	2.8
CarbonCure w/CO2 (2210)	2.2	5.7	0.105	147.1	81.3	1.0
Burgess Pigment (2220)	4.3	8.7	0.115	139.6	77.0	1.0
Hess (2222)	1.8	6.4	0.230	144.0	76.0	1.0
3M (2221)	2.1	5.3	0.180	145.1	77.0	1.0
Ash Grove IP(30) (2214)	1.4	7.8	0.185	142.1	77.0	1.8
Continental IL(20) (2223)	1.7	5.2	0.210	148.1	83.0	1.5
UltraHigh (2209)	0.6	9.2	0.335	142.2	80.5	3.3
Carbon Limit (2224)	0.6	5.2	0.360	146.1	80.5	2.0
Carbon Upcycling (2213)	1.3	4.9	0.395	147.0	76.3	1.0
Terra CO2 (2216)	3.5	7.3	0.095	143.1	77.3	1.0

Material (Cell #)	Slump (in)	Air Content (%)	SAM Number	Unit Weight (lb/ft^3)	Concrete Delivery Temperature (°F)	Average Box Test Rating
Urban Mining (2215)	1.9	7.2	0.210	144.1	77.0	1.0

6.3 Compressive Strength

Compressive cylinders were cast on the day of construction and tested through 56 days (Table 15; Figure 5). A compressive strength criteria was not specified.

Table 14. Summary of hardened air content test results

Material (Cell #)	Air Content (%)	Spacing Factor (in)	Specific Surface (in^2/in^3)
Study Control (2218)	5.5	0.051	2,020
Optimized (2219)	4.4	0.076	1,580
CarbonCure Control w/CO2 (2211)	5.9	0.076	1,320
CarbonCure Control wo/CO2 (2217)	5.4	0.076	1,530
CarbonCure wo/CO2 (2212)	5.8	0.076	1,360
CarbonCure w/CO2 (2210)	5.2	0.102	1,320
Burgess Pigment (2220)	7.4	0.051	2,000
Hess (2222)	7.6	0.051	1,660
3M (2221)	5.5	0.076	1,450
Ash Grove IP(30) (2214)	8.8	0.051	1,720
Continental IL(20) (2223)	4.8	0.102	1,330

Material (Cell #)	Air Content (%)	Spacing Factor (in)	Specific Surface (in^2/in^3)
UltraHigh (2209)	6.6	0.102	1,130
Carbon Limit (2224)	3.7	0.102	1,500
Carbon Upcycling (2213)	4.5	0.127	990
Terra CO2 (2216)	7.9	0.051	1,610
Urban Mining (2215)	6.3	0.076	1,370

6.4 Flexural Strength

Flexural strength beams were cast on construction day and tested at a variety of times to capture early- and late-age strengths (Table 16; Figure 6). The specified minimum flexural strength of 500 psi at 28 days was achieved by almost all mixtures. Flexural test results in some cases are variable and do not uniformly follow expected trends with increasing strength gain over time. Casting flexural strength beams with stiff concrete, especially early-stiffening concrete, can be difficult and may result in poor testing results.

Table 15. Average compressive strength (psi) of each material over time (days)

Material (Cell #)	Age 1 Day	Age 3 Days	Age 7 Days	Age 14 Days	Age 28 Days	Age 42 Days	Age 56 Days
UltraHigh (2209)	2,248	4,152	4,511	5,597	6,551	6,314	6,029
CarbonCure w/CO2 (2210)	2,052	2,498	3,143	3,825	5,115	5,052	4,710
CarbonCure Control w/CO2 (2211)	1,887	2,688	3,220	3,980	4,990	4,903	5,420
CarbonCure wo/CO2 (2212)	1,813	2,460	3,125	3,752	5,020	5,153	5,690
Carbon Upcycling (2213)	2,155	2,803	3,397	3,988	5,005	4,688	5,385
Ash Grove IP(30) (2214)	1,963	2,493	3,038	3,492	3,535	3,733	4,380
Urban Mining (2215)	2,370	2,938	3,163	3,838	4,245	4,753	4,890
Terra CO2 (2216)	1,563	1,912	2,327	2,912	3,060	3,158	3,645
CarbonCure Control wo/CO_2	1,947	2,438	3,063	3,703	4,552	4,837	5,150
Study Control (2218)	1,980	2,665	3,143	3,645	3,915	4,265	4,845
Optimized (2219)	2,173	2,565	3,025	3,400	4,178	4,220	4,835
Burgess Pigment (2220)	1,912	2,258	2,697	2,782	3,100	2,865	3,305
3M (2221)	1,923	2,637	3,223	3,277	3,960	3,688	4,150
Hess (2222)	1,792	2,158	2,665	2,833	3,245	3,252	3,330
Continental IL(20) (2223)	1,750	2,367	2,967	3,982	5,050	5,422	5,710
Carbon Limit (2224)	2,633	3,403	4,170	4,765	4,933	4,895	5,255

6.5 Rapid Chloride Permeability

The rapid chloride permeability (RCP) test gives an indication of a concrete mixture's resistance to chloride ion penetration. The RCP test was carried out on the day of construction (Table 17; Figure 7). In general, the fewer coulombs pass through the sample, the lower the permeability of the concrete[8].

[8] The relationship between coulombs passed and permeability is not universal, and is influenced by the conductivity of the pore solution. These reported values do not include a correction for the pore solution chemistry. See AASHTO R 101 for additional information and a description of the F-Factor.

Table 16. Average flexural strength (psi) of each material over time (days)

Material (Cell #)	Age 3 Days	Age 7 Days	Age 28 Days	Age 56 Days
UltraHigh (2209)	385	283	380	#N/A
CarbonCure w/CO2 (2210)	453	528	655	740
CarbonCure Control w/CO2 (2211)	460	483	640	668
CarbonCure wo/CO2 (2212)	425	505	700	700
Carbon Upcycling (2213)	423	548	683	715
Ash Grove IP(30) (2214)	450	520	565	580
Urban Mining (2215)	455	515	700	793
Terra CO2 (2216)	410	388	463	530
CarbonCure Control wo/CO_2	443	500	750	703
Study Control (2218)	450	483	590	633
Optimized (2219)	545	555	608	720
Burgess Pigment (2220)	480	580	640	578
3M (2221)	408	445	518	615
Hess (2222)	428	455	543	615
Continental IL(20) (2223)	390	490	633	738
Carbon Limit (2224)	480	558	683	620

6.6 Resistivity

Resistivity samples were cast on the day of construction. The results of the resistivity testing are shown in Table 18 and plotted in Figure 8. In general, the higher the resistivity of the sample, the lower the permeability of the concrete[9].

Table 17. Summary of RCP test results

Material (Cell #)	56-Day Coulombs
Study Control (2218)	1,139
Optimized (2219)	942
CarbonCure Control w/CO2 (2211)	1,433
CarbonCure Control wo/CO2 (2217)	1,387
CarbonCure wo/CO2 (2212)	1,516
CarbonCure w/CO2 (2210)	2,008
Burgess Pigment (2220)	544
Hess (2222)	2,466
3M (2221)	2,714
Ash Grove IP(30) (2214)	1,940
Continental IL(20) (2223)	1,008
UltraHigh (2209)	76
Carbon Limit (2224)	636
Carbon Upcycling (2213)	902
Terra CO2 (2216)	1,314
Urban Mining (2215)	474

[9] The relationship between resistivity and permeability is influenced by the conductivity of the pore solution. These reported values do not include a correction for the pore solution chemistry. See AASHTO R 101 for additional information and a description of the F-Factor.

Table 18. Resistivity (kW•cm) of each material over time (days)

Material (Cell #)	1	3	7	14	28	42	56
UltraHigh (2209)	63.8	143.1	162.1	230.6	283.3	228.9	247.0
CarbonCure w/CO2 (2210)	5.5	6.9	7.8	10.3	15.0	21.2	26.7
CarbonCure Control w/CO2 (2211)	5.1	6.5	8.9	10.8	15.5	21.7	31.1
CarbonCure wo/CO2 (2212)	5.6	6.7	9.3	10.5	15.8	22.2	30.6
Carbon Upcycling (2213)	3.9	5.2	7.7	13.3	22.9	32.0	46.7
Ash Grove IP(30) (2214)	4.2	6.2	10.5	17.2	25.7	29.9	40.5
Urban Mining (2215)	5.8	7.1	11.1	19.4	40.5	61.0	63.4
Terra CO2 (2216)	5.7	7.6	8.7	10.8	16.7	23.4	32.1
CarbonCure Control wo/CO2	5.8	7.4	8.0	9.6	16.4	23.1	25.6
Study Control (2218)	6.1	7.8	10.5	12.2	21.7	31.7	35.4
Optimized (2219)	7.0	9.2	11.1	13.3	22.9	29.9	40.9
Burgess Pigment (2220)	12.7	23.1	35.5	43.8	55.1	61.4	67.9
3M (2221)	4.7	6.2	7.3	7.9	10.0	13.1	14.5
Hess (2222)	4.9	6.4	7.3	8.8	13.5	19.5	24.1
Continental IL(20) (2223)	5.8	7.9	8.9	11.5	22.0	32.9	42.9
Carbon Limit (2224)	5.6	7.4	16.7	30.5	46.0	58.9	66.5

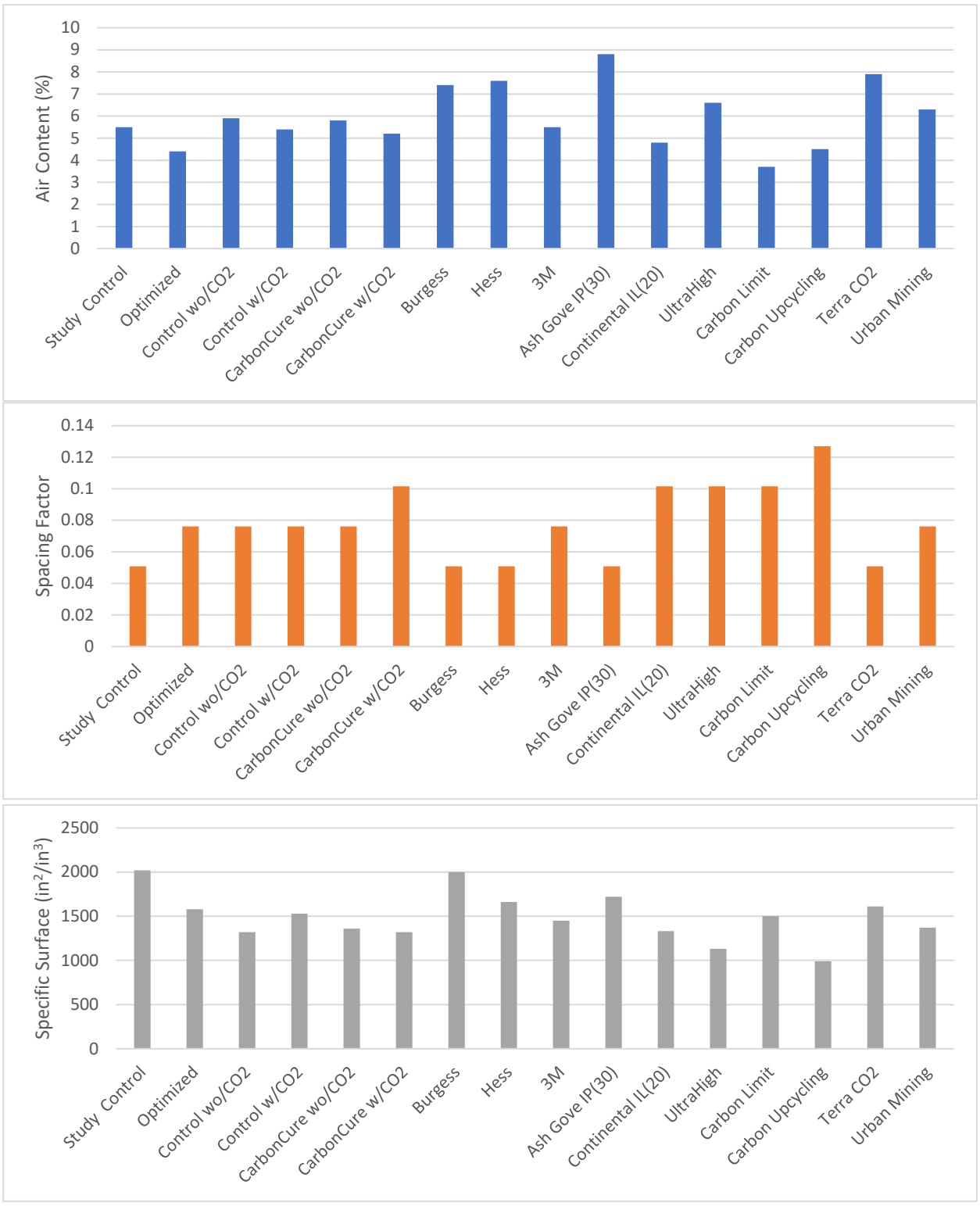


Figure 4. Hardened air test results for air content (top), spacing factor (middle), and specific surface (bottom)

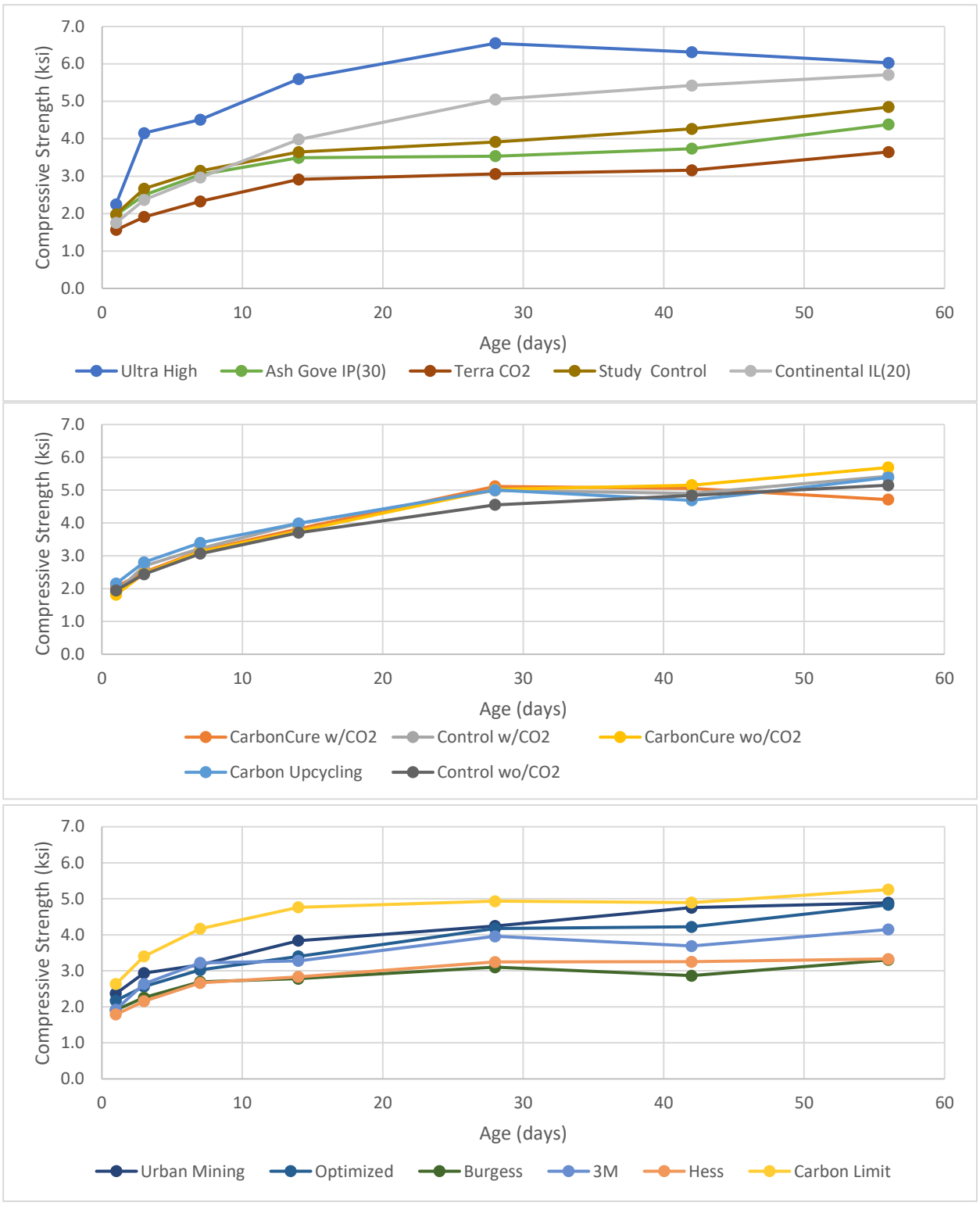


Figure 5. Compressive strength results for alternative cements (top), carbon dioxide (middle), and alternative pozzolans (bottom)

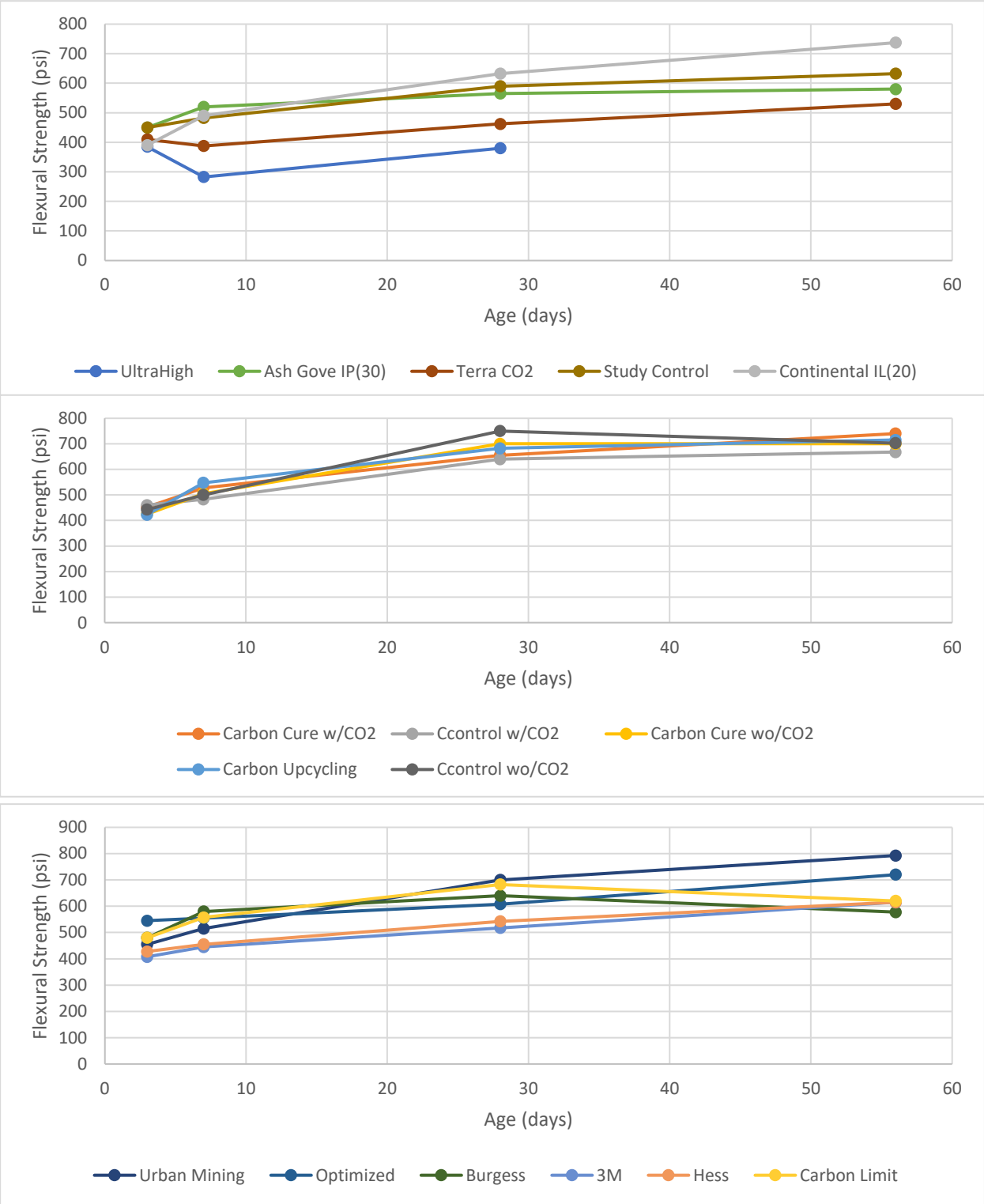


Figure 6. Flexural strength results for alternative cements (top), carbon dioxide (middle), and alternative pozzolans (bottom)

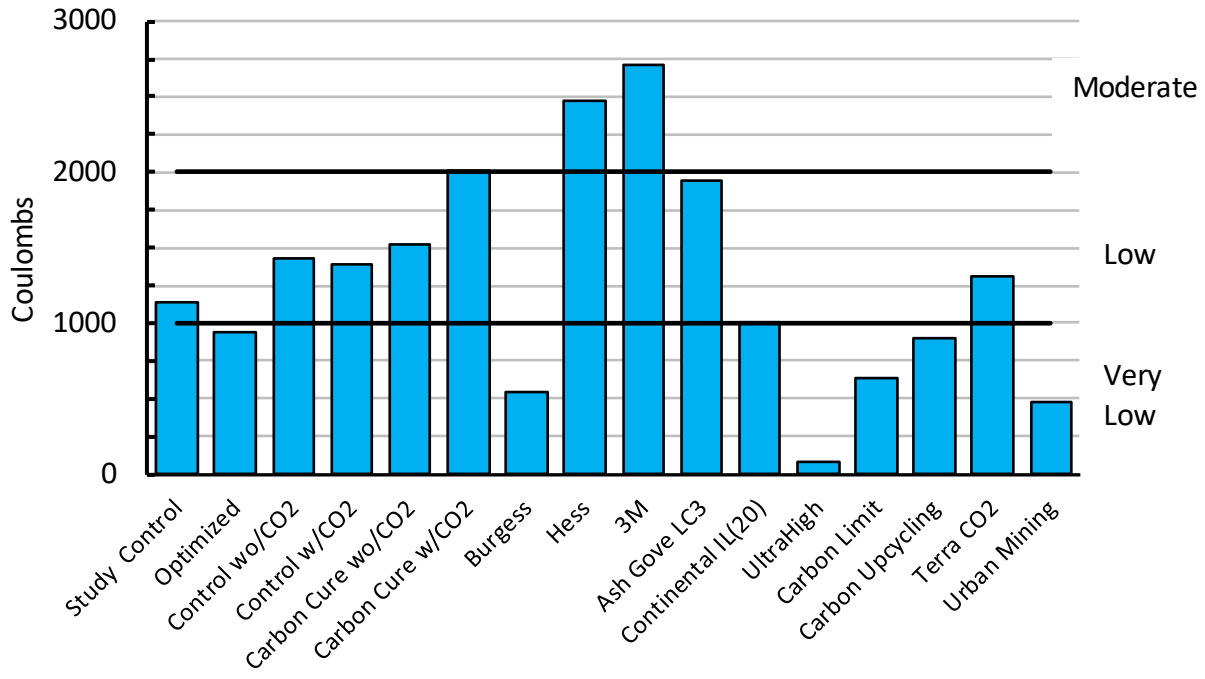


Figure 7. RCP test results for alternative cements (top), carbon dioxide (middle), and alternative pozzolans (bottom)

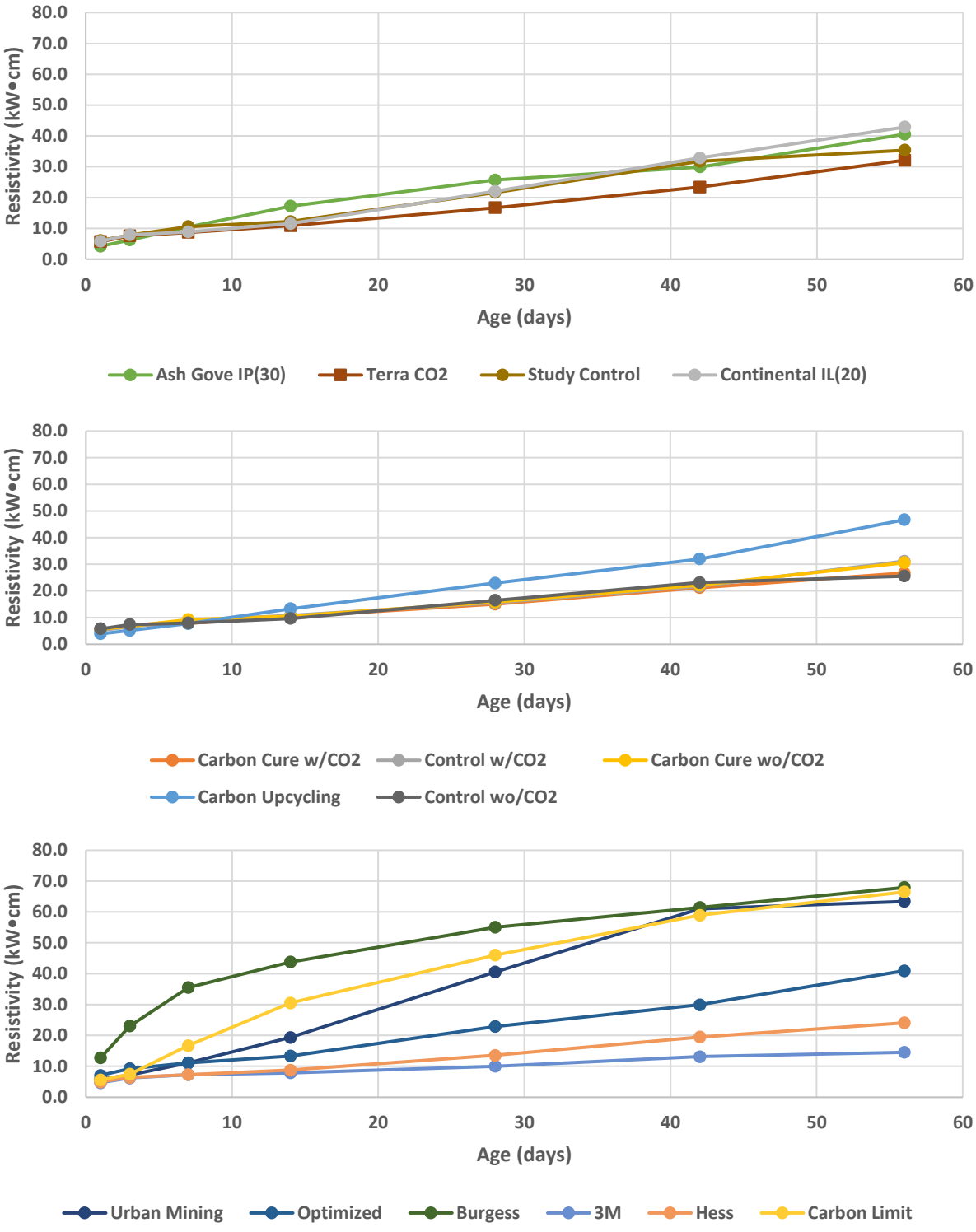


Figure 8. Resistivity test results for alternative cements (top), carbon dioxide (middle), and alternative pozzolans (bottom)

Chapter 7: Summary and Conclusions

Between July 27 and August 9, 2023, 16 test cells were constructed at the MnROAD I-94 facility to evaluate reduced ECC concrete paving mixtures. The purpose of constructing these cells was to assess the in-service performance, environmental impact and constructability of various paving mixtures designed with alternative materials that may reduce the embodied carbon content of concrete while providing an opportunity to assess test results and in-service performance in coming years.

The concrete mixtures included in the test had to meet basic engineering properties to ensure constructability and have the potential to perform in service. A large list of materials was considered including alternative cementitious materials (ACMs), alternative supplementary cementitious materials (ASCMs), and calcium carbonate mineralization. The following criteria were used to identify materials and technologies for consideration in the study:

- The material producer had to be capable of delivering sufficient material by spring 2022 to construct a nominally 270-ft-long, 29-ft-wide, and 7.5-inch-thick test cell.
- The final concrete mixture designs were required to meet specified fresh and hardened concrete performance properties, identified as part of this project.
- All mixtures were required to be batched and mixed in a conventional concrete plant, transported using conventional concrete trucks with a time to initial set of at least 45 minutes, and capable of placement using a conventional slipform paver.
- All materials were required to have the potential to be market-ready, including scalable material availability, and the ability to be integrated into conventional concrete production and placement.
- Cooperation of the material supplier was required to conduct trial batching and demonstrate that required concrete properties could be met.

The final test matrix of 16 cells is shown in Table 3, and is summarized as follows:

- One control mixture was representative of typical MnDOT paving-grade concrete with 570 pcy total cementitious materials, Holcim Ste. Genevieve Plant AASHTO M 240 Type IL(8), and 30% Coal Creek AASHTO M 295 Class F fly ash. Another control mixture was for the calcium carbonate mineralization tests and used a Continental Davenport AASHTO M 240 Type IL(10)
- One optimized concrete mixture with 501 pcy total cementitious materials content and 30% Coal Creek fly ash
- Three calcium carbonate mineralization test cells

- One ACM that does not contain Portland cement clinker
- One blended cement with 20% interground limestone (higher limestone replacement that AASHTO M 240 currently allows) with 30% Class F fly ash
- One blended cement meeting AASHTO M 240 Type IP(30) made with calcined clay
- Three containing natural pozzolans meeting AASHTO M 295 Class N
- One ground glass pozzolan meeting ASTM C1866
- Three processed/manufactured ASCMs

Mixture proportions were determined through laboratory trial batching. A preliminary qualitative assessment of the ECC of the mixtures (cradle-to-gate) was conducted. An environmental product declaration (EPD) was obtained for the control mixture showing that the use of the Type IL(8) PLC with 30% replacement with Class F fly ash resulted in a relatively low ECC of 220 $kgCO_2eq/m^3$ (169 $kgCO_2eq/cy$), which falls well below the 20% "achievable" value obtained from the EC3 Tool. Mixtures with reduced Portland cement clinker content in the cementitious materials and reduced overall cementitious materials content had lower ECCs.

For the most part, construction went well, and most mixtures met the desired fresh concrete specifications. Several mixtures required more water than expected, most test cells required diamond grinding to provide texture, and early setting was an issue for some test cells, making them difficult to finish and texture. In an extreme case, the ACM material underwent rapid early setting and much of the test cell had to be removed. This was believed to be attributed to contamination of the ACM with Portland cement in the silo at the concrete plant, but this has not been verified.

Quality assurance testing conducted on field cast specimens revealed generally acceptable results.

At the time of this report, all test cells were still in service at MnROAD, proving the materials tested could be batched, transported, placed, and finished. Some immediate takeaways from this experiment include:

- Material suppliers, especially of novel ASCMs, are not always familiar with the needs of large-scale production. Guidance may be needed to encourage thorough blending of multi-component mixtures.
- Shipping cementitious materials in super sacks should be highly discouraged.
- Ready mixed concrete suppliers may not be familiar with the need to use specialized admixtures with some materials, and the increase in water demand inherent in others. Early setting was an issue with several materials.
- In several cases, early setting resulted in poor consolidation and tearing of the freshly placed concrete and made it very difficult to finish and texture some of the test cells. The difficulties arose early, and in

most cases, the concrete supplier was able to make adjustments to improve mixture workability. However, with such short test cells (nominally 270-ft long), the paving ended before the adjustments could be fully manifested. With experience, most of the materials can likely be adjusted and used in production.

- It should be noted that most of these mixtures were not optimized for paving. The producers chose to use the standard aggregate gradation and cementitious content. Those that did optimize did so for carbon reduction, not paving. It is reasonable to expect that all these materials could improve their performance for paving if optimized for that purpose.

References

Choate, W. 2003. *Energy and Emissions Reduction Opportunities for the Cement Industry*. Prepared for the Industrial Technologies Program, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. December 29.

Appendix A: Concrete Mix Designs and Other Material Information

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Ultra High Materials	UHMSCM		2.70
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	FSIVI1000	F	4-12
Admx#3	Retarder	Proprietary	*	0.01%
Admx#4				
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CIA#1	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-206**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													54		16	22	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGH1	7.0	152	0			660			100		660	0.23	1662		500	693	250	27.0	145.1	23.5	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Ultra High Materials for MNRoad
*Reatrder blended with SCM on the belt

Submit to: conc1off.dot@state.mn.us

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Ultra High Materials	UHMSCM		2.70
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	FSIVI1000	F	4-12
Admx#3	Retarder	Proprietary	*	0.01%
Admx#4				
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CIA#1	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-206**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													54		16	22	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGH1	7.0	152	0			660			100		660	0.23	1662		500	693	250	27.0	145.1	23.5	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Ultra High Materials for MNRoad
*Reatrder blended with SCM on the belt

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

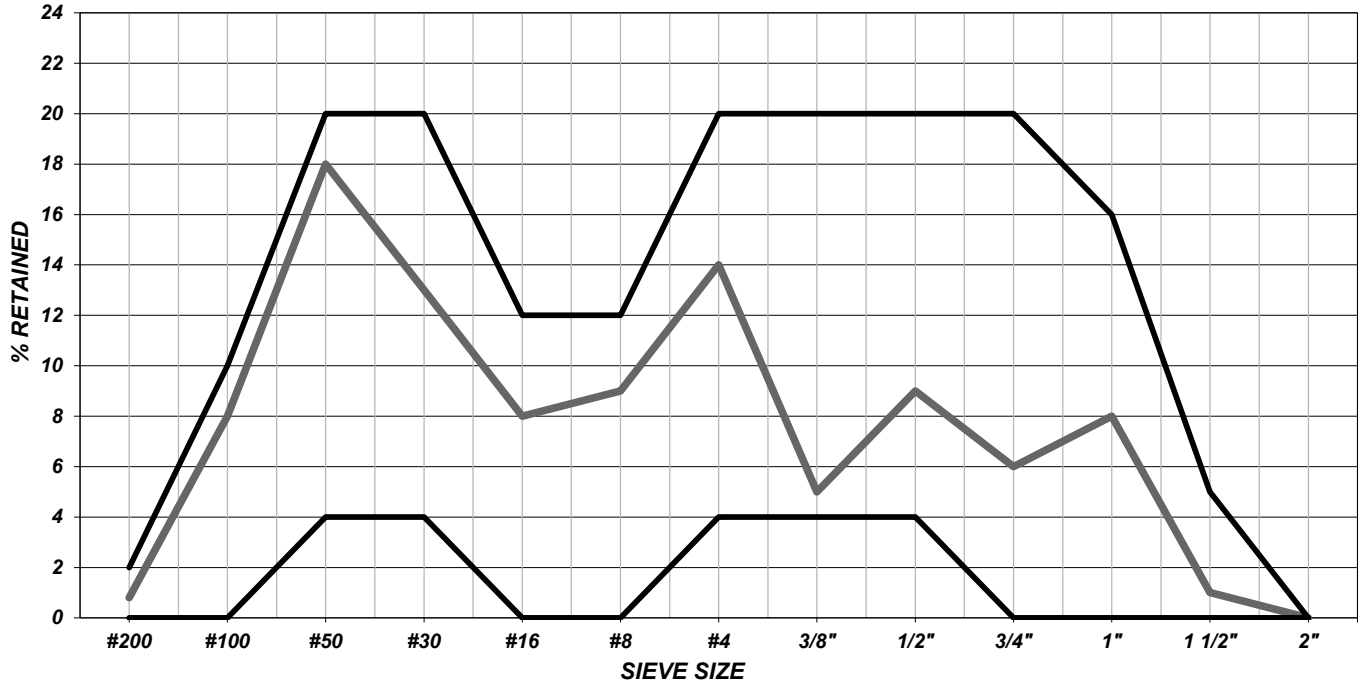
JMF **22-206**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	54		16	22	8	**100%**	**LIMITS**			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**91**	± 5	86	96	**8**
3/4"	100.0		8.5	99.0	100.0	**85**	± 5	80	90	**6**
1/2"	100.0		0.4	64.4	100.0	**76**	± 5	71	81	**9**
3/8"	100.0		0.2	40.4	98.2	**71**	± 5	66	76	**5**
#4	99.0		0.0	4.1	32.9	**57**	± 5	52	62	**14**
#8	88.2		0.0	0.0	0.8	**48**	± 4	44	52	**9**
#16	74.4		0.0	0.0	0.1	**40**	± 4	36	44	**8**
#30	50.7		0.0	0.0	0.0	**27**	± 4	23	31	**13**
#50	17.0		0.0	0.0	0.0	**9**	± 3	6	12	**18**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**8**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGH1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
30
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
40
Between 24-34%, generally enhances workability of the mix.

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Contin./Davenport	CONDAIL	IL(10)	3.10
Fly Ash	EM/Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	MBS	MAIR90	AEA	0.1-10
Admx#2	MBS	AMPOL1020	A	0-12
Admx#3	MBS	SMMAT358	S	0-6
Admx#4	MBS	BMSTDELVO	B	0-5
Admx#5	MBS	SMSREZ60	S	0-12
Other	Carbon Cure	SCCCO2	S	6
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71002	SAND		2.66	0.008
FA#2					
CA#1	71002	#67	C	2.70	0.014
CA#2	71002	3/4"+	C	2.65	0.016
CA#3					

SP Number	8680-191
Contract ID	220071
Requested By	Kevin Heindel
Company	Cemstone Products Company
Phone	651-686-4233
Email	kheindel@cemstone.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Cemstone - Dayton (#16)
Plant/Unit #	RM229
Contractor	PCI Roads
JMF Number	**22-178**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													45		42	13					
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGCC	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC1	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3
3A21-RGC2	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC3	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Mixes 3A21-RGC1 and 3A21-RGC2 will have 6 oz/yd of CarbonCure.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

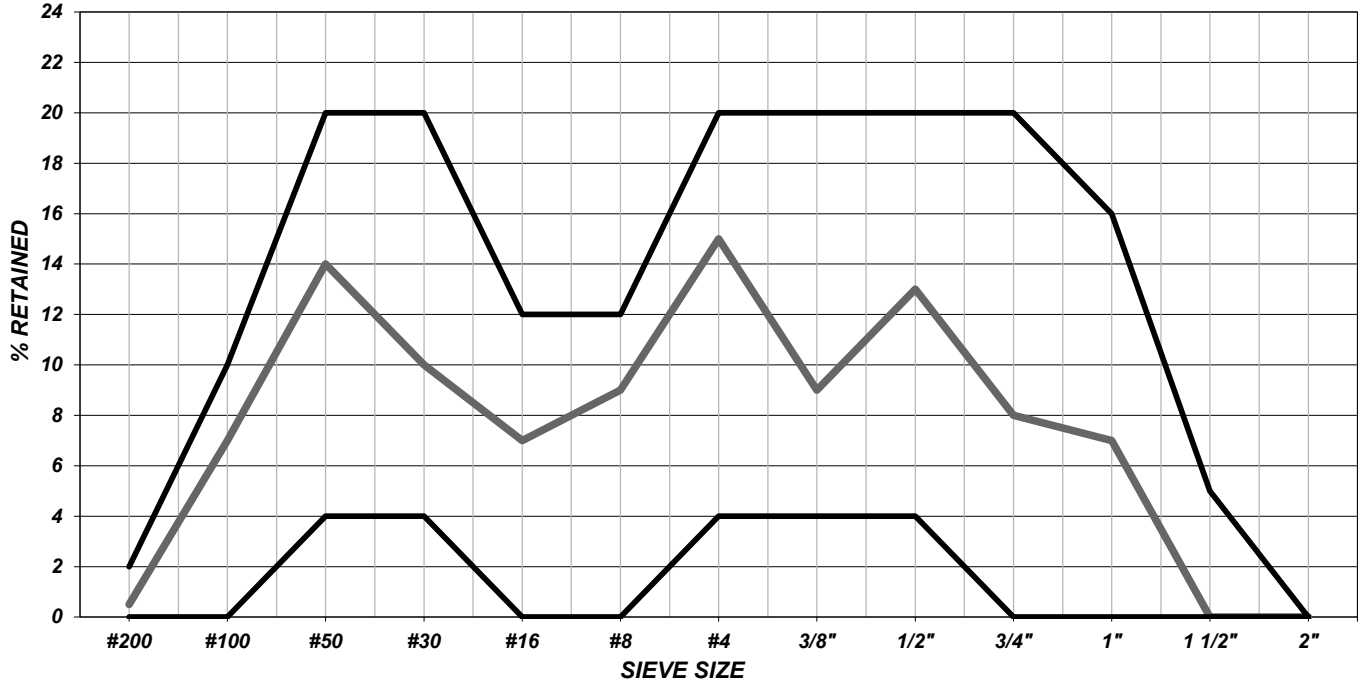
JMF **22-178**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		**100%**	**LIMITS**			
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		100.0	49.0		**93**	± 5	88	98	**7**
3/4"	100.0		95.0	3.0		**85**	± 5	80	90	**8**
1/2"	100.0		63.0	1.0		**72**	± 5	67	77	**13**
3/8"	100.0		43.0	0.0		**63**	± 5	58	68	**9**
#4	99.0		8.0	0.0		**48**	± 5	43	53	**15**
#8	87.0		0.0	0.0		**39**	± 4	35	43	**9**
#16	71.0		0.0	0.0		**32**	± 4	28	36	**7**
#30	48.0		0.0	0.0		**22**	± 4	18	26	**10**
#50	17.0		0.0	0.0		**8**	± 3	5	11	**14**
#100	3.0		0.0	0.0		**1**	± 2	0	3	**7**
#200	1.0		0.0	0.0		**0.5**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGCC
3A21-RGC1
3A21-RGC2
3A21-RGC3

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Contractor Mix Design - Job Mix Formula (JMF)

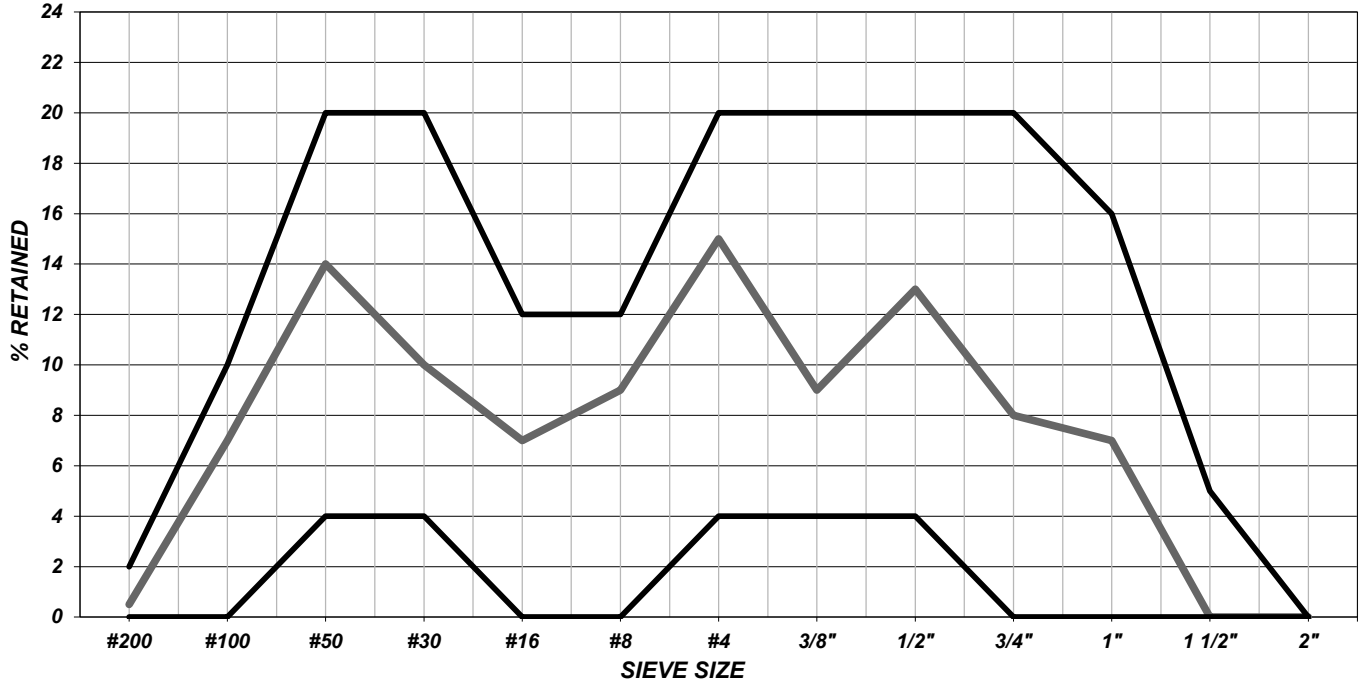
JMF **22-178**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		**100%**	**LIMITS**			
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		100.0	49.0		**93**	± 5	88	98	**7**
3/4"	100.0		95.0	3.0		**85**	± 5	80	90	**8**
1/2"	100.0		63.0	1.0		**72**	± 5	67	77	**13**
3/8"	100.0		43.0	0.0		**63**	± 5	58	68	**9**
#4	99.0		8.0	0.0		**48**	± 5	43	53	**15**
#8	87.0		0.0	0.0		**39**	± 4	35	43	**9**
#16	71.0		0.0	0.0		**32**	± 4	28	36	**7**
#30	48.0		0.0	0.0		**22**	± 4	18	26	**10**
#50	17.0		0.0	0.0		**8**	± 3	5	11	**14**
#100	3.0		0.0	0.0		**1**	± 2	0	3	**7**
#200	1.0		0.0	0.0		**0.5**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGCC
3A21-RGC1
3A21-RGC2
3A21-RGC3

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Contin./Davenport	CONDAIL	IL(10)	3.10
Fly Ash	EM/Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	MBS	MAIR90	AEA	0.1-10
Admx#2	MBS	AMPOL1020	A	0-12
Admx#3	MBS	SMMAT358	S	0-6
Admx#4	MBS	BMSTDELVO	B	0-5
Admx#5	MBS	SMSREZ60	S	0-12
Other	Carbon Cure	SCCCO2	S	6
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71002	SAND		2.66	0.008
FA#2					
CA#1	71002	#67	C	2.70	0.014
CA#2	71002	3/4"+	C	2.65	0.016
CA#3					

SP Number	8680-191
Contract ID	220071
Requested By	Kevin Heindel
Company	Cemstone Products Company
Phone	651-686-4233
Email	kheindel@cemstone.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Cemstone - Dayton (#16)
Plant/Unit #	RM229
Contractor	PCI Roads
JMF Number	**22-178**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													45		42	13					
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGCC	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC1	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3
3A21-RGC2	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC3	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Mixes 3A21-RGC1 and 3A21-RGC2 will have 6 oz/yd of CarbonCure.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

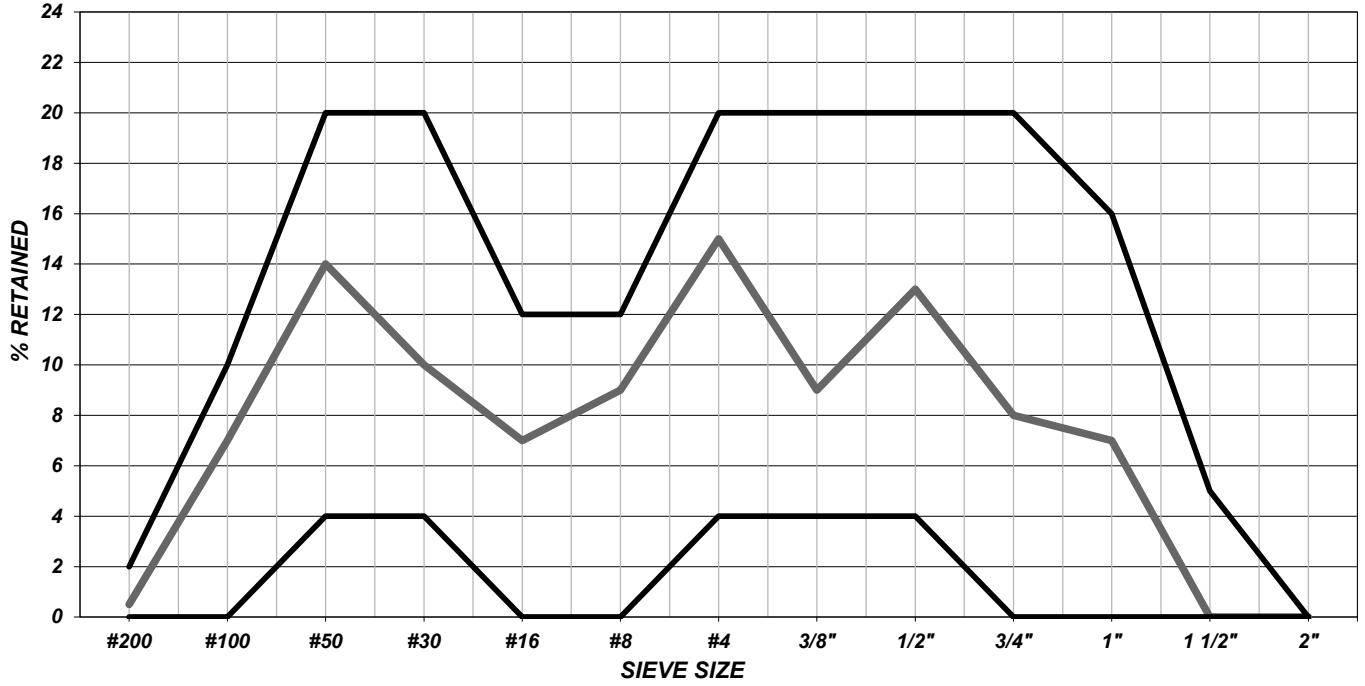
JMF **22-178**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		**100%**	**LIMITS**			
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		100.0	49.0		**93**	± 5	88	98	**7**
3/4"	100.0		95.0	3.0		**85**	± 5	80	90	**8**
1/2"	100.0		63.0	1.0		**72**	± 5	67	77	**13**
3/8"	100.0		43.0	0.0		**63**	± 5	58	68	**9**
#4	99.0		8.0	0.0		**48**	± 5	43	53	**15**
#8	87.0		0.0	0.0		**39**	± 4	35	43	**9**
#16	71.0		0.0	0.0		**32**	± 4	28	36	**7**
#30	48.0		0.0	0.0		**22**	± 4	18	26	**10**
#50	17.0		0.0	0.0		**8**	± 3	5	11	**14**
#100	3.0		0.0	0.0		**1**	± 2	0	3	**7**
#200	1.0		0.0	0.0		**0.5**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGCC
3A21-RGC1
3A21-RGC2
3A21-RGC3

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Carbon Upcycling	CUCAAL		2.55
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-181**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													41		14	37	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGU1	7.0	200	350			150			30		500	0.40	1289		447	1190	255	27.0	143.7	22.1	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Carbon Upcycling 30% ASCM

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

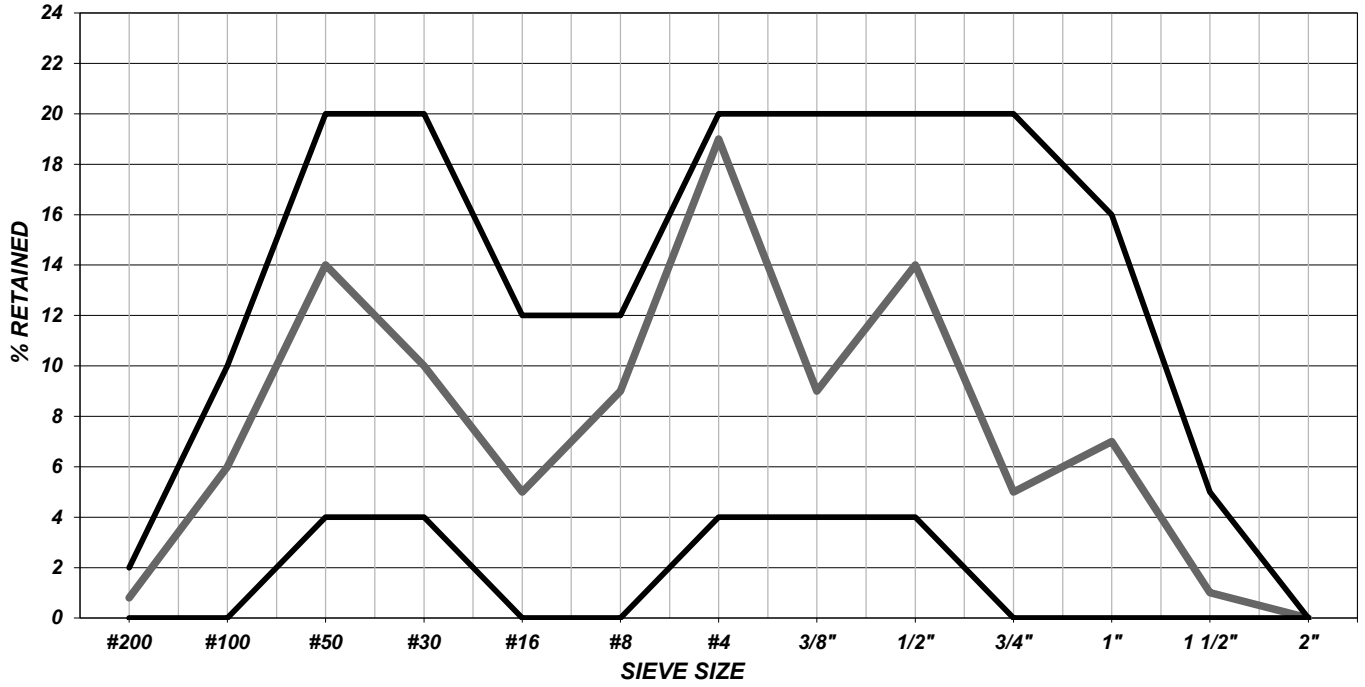
JMF **22-181**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4"+	#67	CIA					
Prop. %	41		14	37	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**87**	± 5	82	92	**5**
1/2"	100.0		0.4	64.4	100.0	**73**	± 5	68	78	**14**
3/8"	100.0		0.2	40.4	98.2	**64**	± 5	59	69	**9**
#4	99.0		0.0	4.1	32.9	**45**	± 5	40	50	**19**
#8	88.2		0.0	0.0	0.8	**36**	± 4	32	40	**9**
#16	74.4		0.0	0.0	0.1	**31**	± 4	27	35	**5**
#30	50.7		0.0	0.0	0.0	**21**	± 4	17	25	**10**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**14**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGU1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
24
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
31
Between 24-34%, generally enhances workability of the mix.

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Ash Grove LC3	ASGLC3		2.90
Fly Ash				
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-180**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	39	7				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGA1	7.0	239	570								570	0.42	1160		453	1187	211	27.0	141.5	25.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Ash Grove LC3 Cement

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

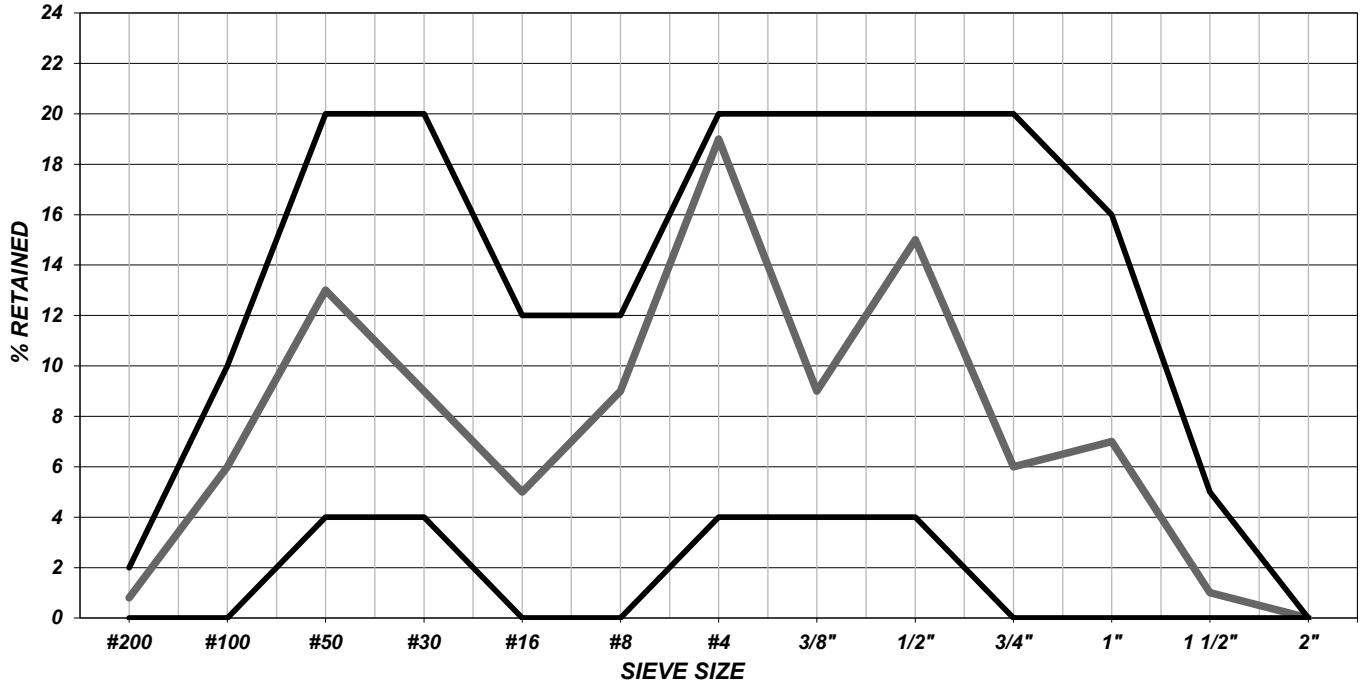
JMF **22-180**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	39	7	**100%**	**LIMITS**			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**71**	± 5	66	76	**15**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**9**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGA1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Pozzotive	UMPOZZ		2.51
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-179**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGM1	7.0	217	400			170			30		570	0.38	1183		462	1179	246	27.0	142.8	24.6	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Urban Mining Pozzotive ASCM

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

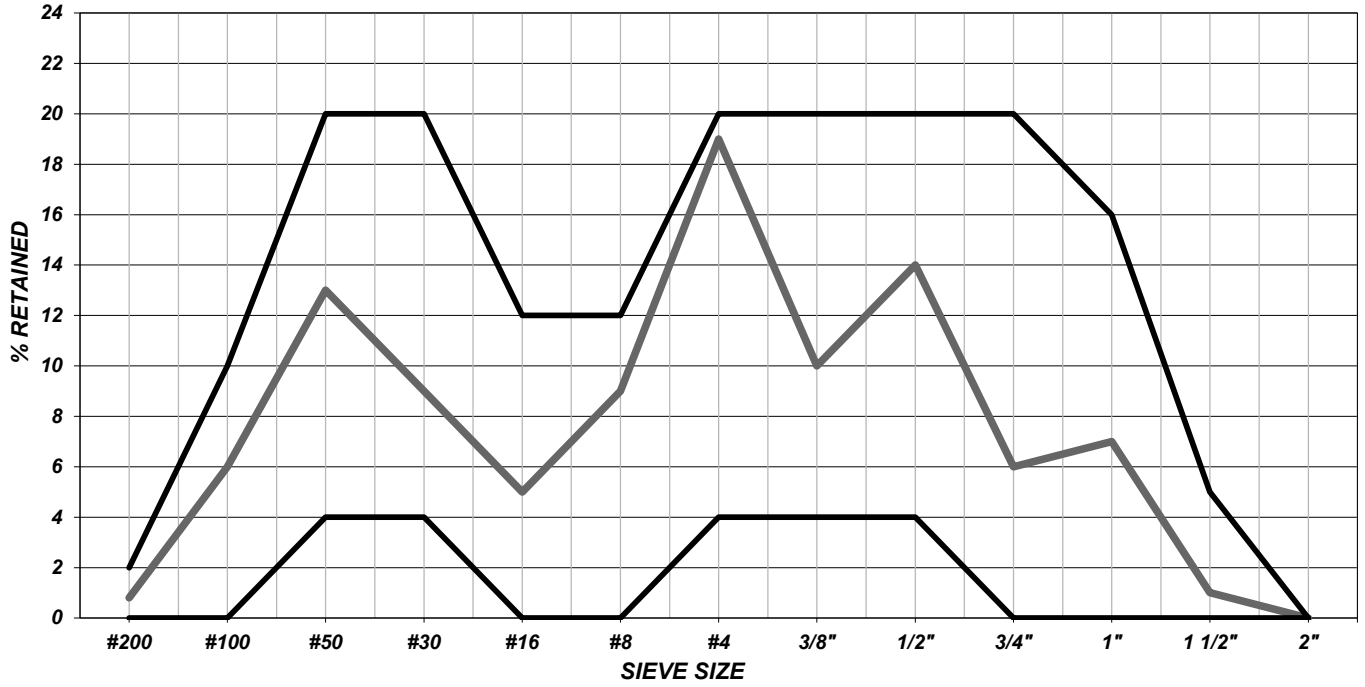
JMF **22-179**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGM1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Opus Terra CO2	TEOPUS		2.58
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-182**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGT1	7.0	217	370			200			35		570	0.38	1183		462	1179	246	27.0	142.8	24.6	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: MNRoad Paving with Terra CO2 Opus SCM

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

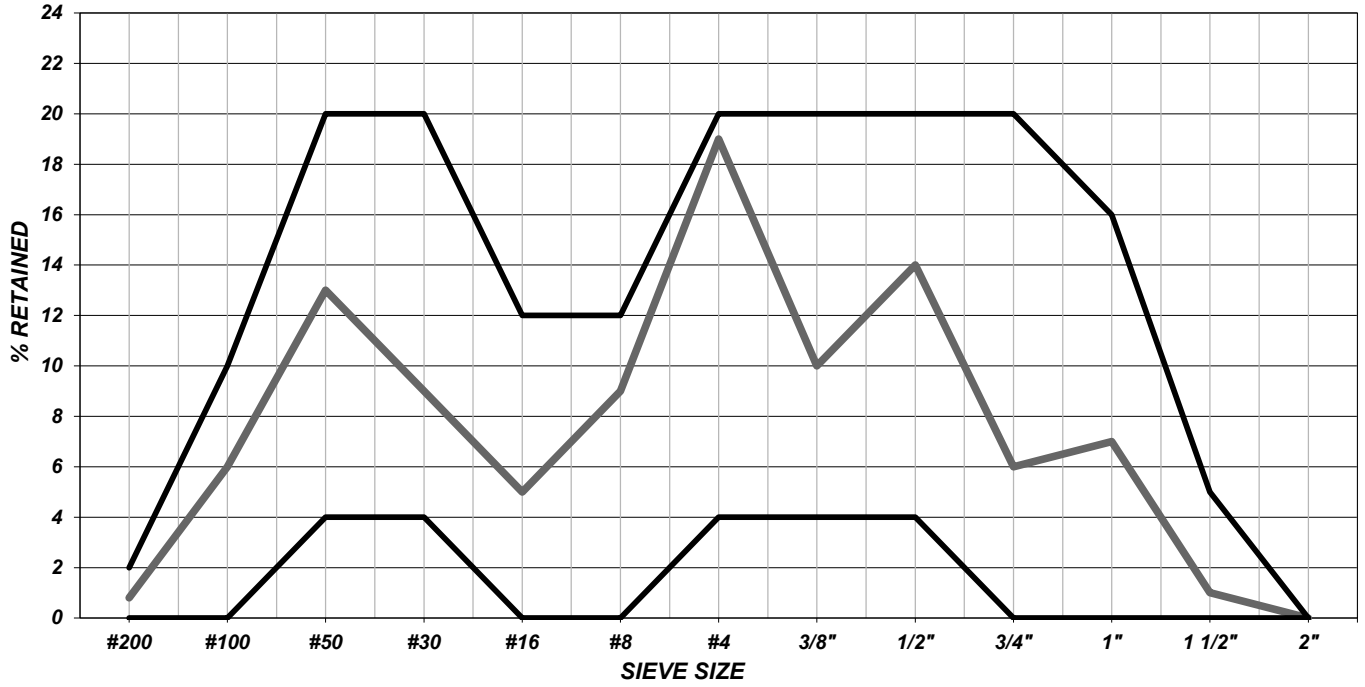
JMF **22-182**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGT1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Contin./Davenport	CONDAIL	IL(10)	3.10
Fly Ash	EM/Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	MBS	MAIR90	AEA	0.1-10
Admx#2	MBS	AMPOL1020	A	0-12
Admx#3	MBS	SMMAT358	S	0-6
Admx#4	MBS	BMSTDELVO	B	0-5
Admx#5	MBS	SMSREZ60	S	0-12
Other	Carbon Cure	SCCCO2	S	6
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71002	SAND		2.66	0.008
FA#2					
CA#1	71002	#67	C	2.70	0.014
CA#2	71002	3/4"+	C	2.65	0.016
CA#3					

SP Number	8680-191
Contract ID	220071
Requested By	Kevin Heindel
Company	Cemstone Products Company
Phone	651-686-4233
Email	kheindel@cemstone.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Cemstone - Dayton (#16)
Plant/Unit #	RM229
Contractor	PCI Roads
JMF Number	**22-178**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													45		42	13					
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGCC	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC1	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3
3A21-RGC2	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-RGC3	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Mixes 3A21-RGC1 and 3A21-RGC2 will have 6 oz/yd of CarbonCure.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

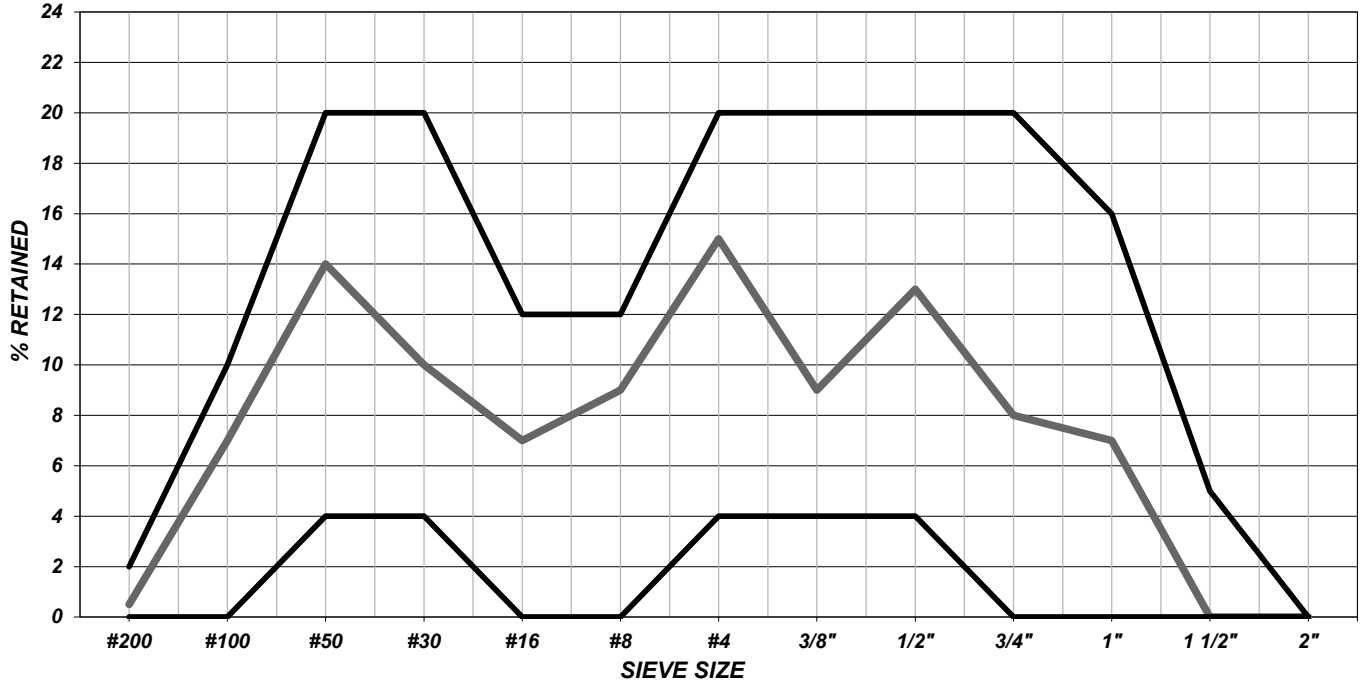
JMF **22-178**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		**100%**	**LIMITS**			
2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1 1/2"	100.0		100.0	100.0		**100**	± 5	95	100	**0**
1"	100.0		100.0	49.0		**93**	± 5	88	98	**7**
3/4"	100.0		95.0	3.0		**85**	± 5	80	90	**8**
1/2"	100.0		63.0	1.0		**72**	± 5	67	77	**13**
3/8"	100.0		43.0	0.0		**63**	± 5	58	68	**9**
#4	99.0		8.0	0.0		**48**	± 5	43	53	**15**
#8	87.0		0.0	0.0		**39**	± 4	35	43	**9**
#16	71.0		0.0	0.0		**32**	± 4	28	36	**7**
#30	48.0		0.0	0.0		**22**	± 4	18	26	**10**
#50	17.0		0.0	0.0		**8**	± 3	5	11	**14**
#100	3.0		0.0	0.0		**1**	± 2	0	3	**7**
#200	1.0		0.0	0.0		**0.5**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGCC
3A21-RGC1
3A21-RGC2
3A21-RGC3

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation (4/28/21)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash	Boral Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Viscocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-184**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGSC	7.0	228	400	170			30				570	0.40	1171		457	1167	244	27.0	142.1	25.2	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: MNRoad Control Mix Design
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

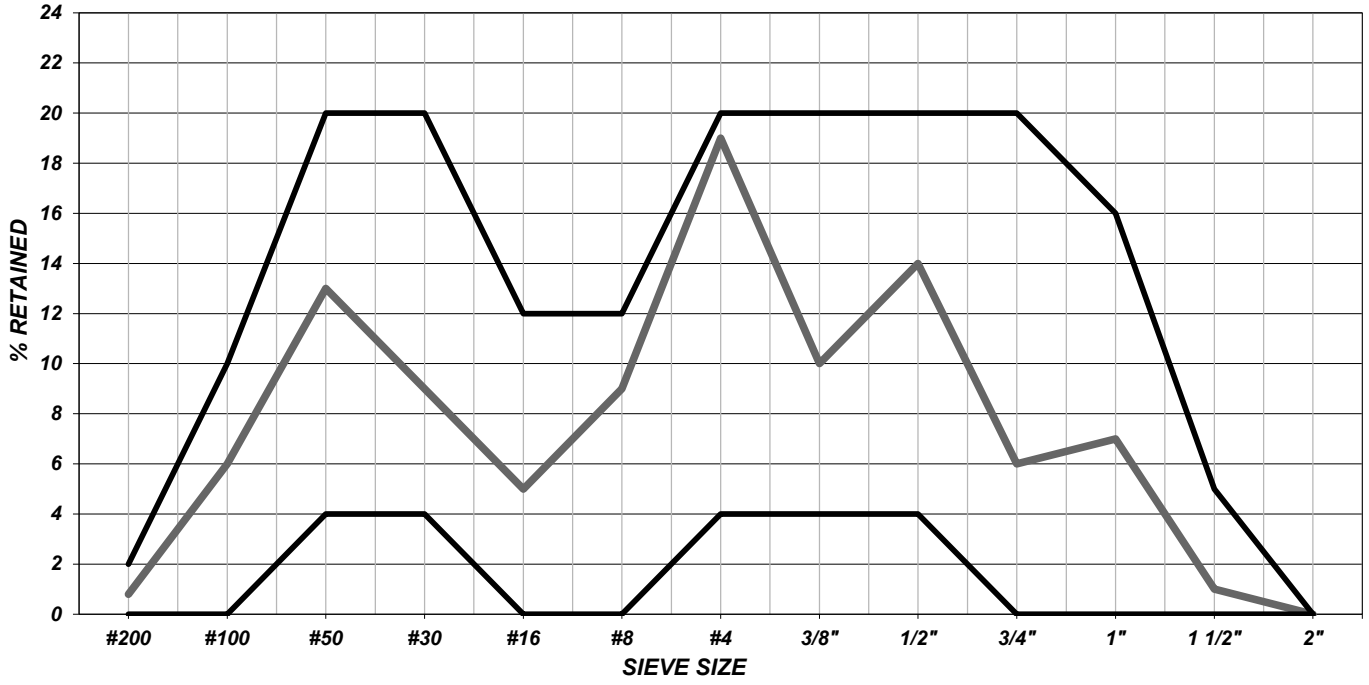
JMF **22-184**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	**100%**				
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGSC

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash	EM Resources	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	0-7
Admx#5	Sika Viscocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	841 - Rogers
Plant/Unit #	81/RM051
Contractor	PCI Roads
JMF Number	**22-183**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													41		21	30	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGI1	7.0	200	351	150			30				501	0.40	1318		669	963	255	27.2	143.7	22.0	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Optimized 3A21-RG paving mix
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

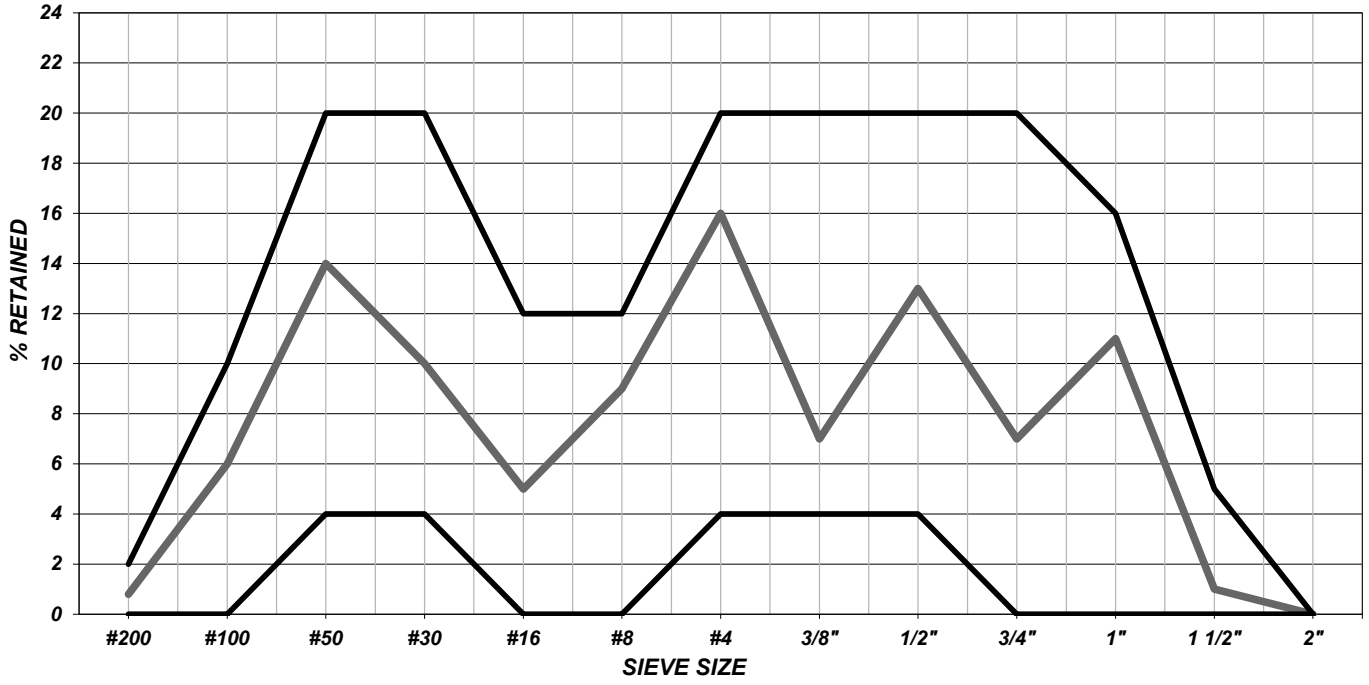
JMF **22-183**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	41		21	30	8	**100%**	**LIMITS**			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**88**	± 5	83	93	**11**
3/4"	100.0		8.5	99.8	100.0	**81**	± 5	76	86	**7**
1/2"	100.0		0.4	64.4	100.0	**68**	± 5	63	73	**13**
3/8"	100.0		0.2	40.4	98.2	**61**	± 5	56	66	**7**
#4	99.8		0.0	4.1	32.9	**45**	± 5	40	50	**16**
#8	88.2		0.0	0.0	0.8	**36**	± 4	32	40	**9**
#16	74.4		0.0	0.0	0.1	**31**	± 4	27	35	**5**
#30	50.7		0.0	0.0	0.0	**21**	± 4	17	25	**10**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**14**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGI1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
24
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
31
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Burgess Optipozz	BPOPTPOZZ		2.51
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Viscocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-189**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGB1	7.0	217	400			170			30		570	0.38	1183		462	1179	246	27.0	142.8	24.6	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Burgess Pigments "Optipozz"
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

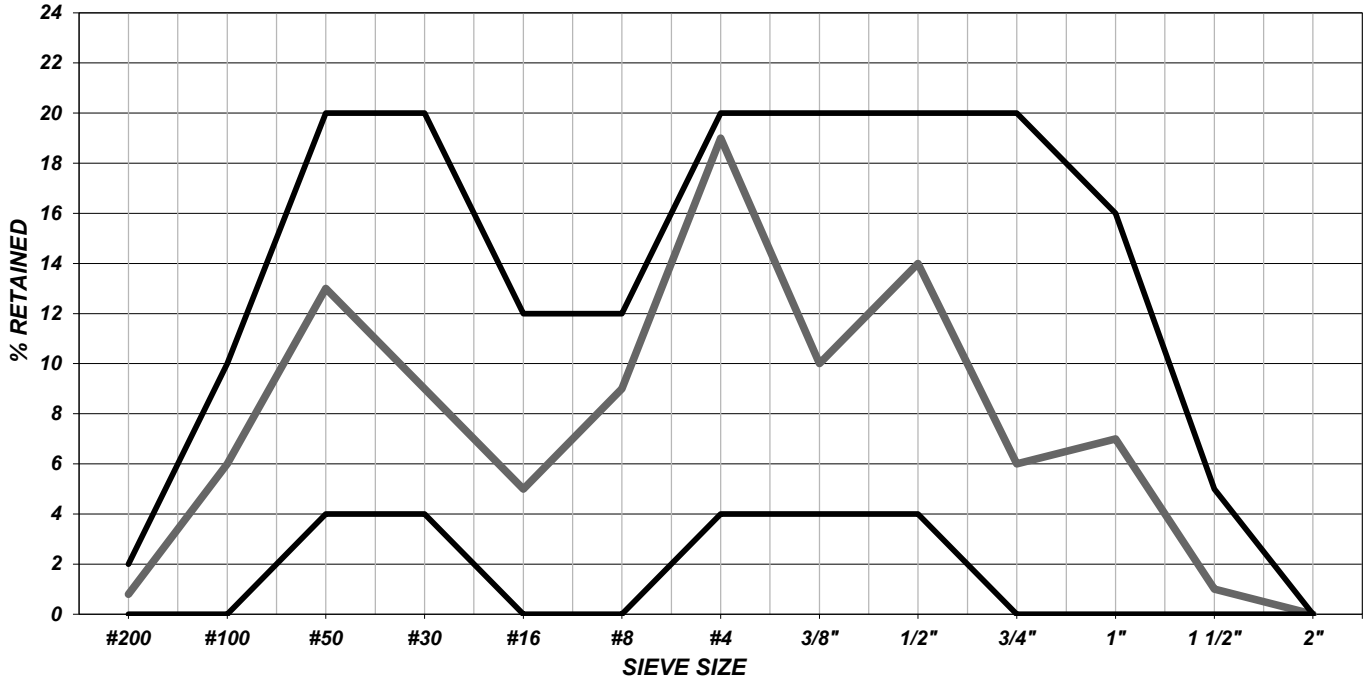
JMF **22-189**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	**100%**				
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGB1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	3M + Prarie State	3MNPPSGS		2.50
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Viscocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-188**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RG31	7.0	239	400			170			30		570	0.42	1160		453	1156	242	27.0	141.5	25.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: 3M Natural Pozzolan and 15% Prairie State Fly Ash blended ASCM
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

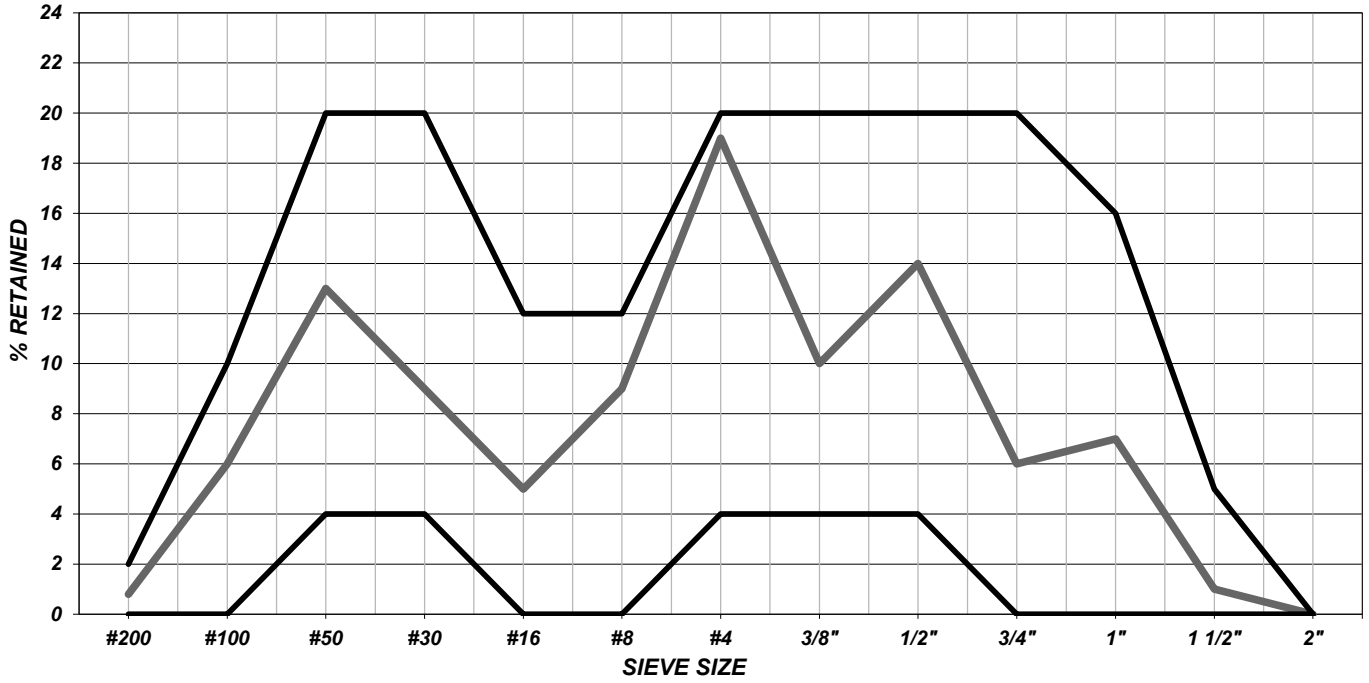
JMF **22-188**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	**100%**				
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RG31

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Hess Pumice Standard	HPPOZZ		2.30
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Viscocrete 1000	FSIVI1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-185**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGP1	7.0	239	400	85		170	13		26	39	655	0.36	1154		451	1150	240	27.0	144.0	26.2	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Hess Pumice ASCM
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

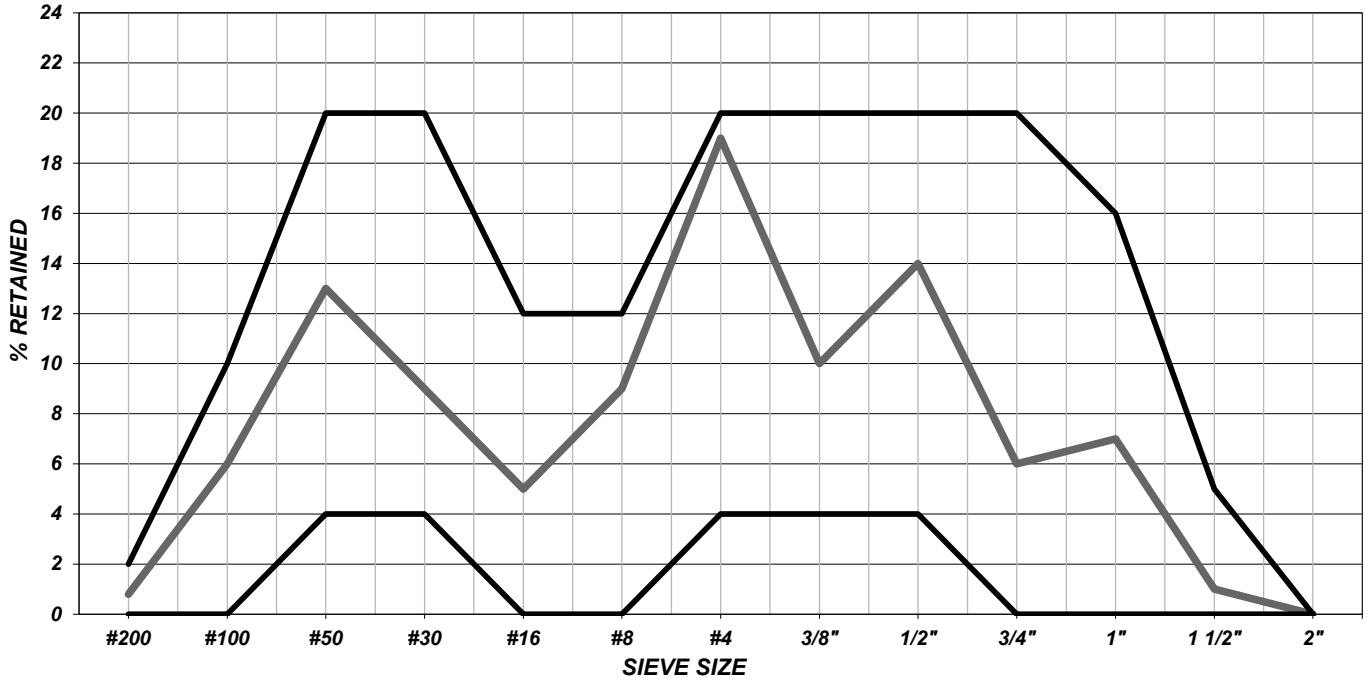
JMF **22-185**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	**100%**	**LIMITS**			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGP1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Continental IL(20)	CONDAIL20		3.15
Fly Ash	EM Resources	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	As Needed
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Viscocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	SAND		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-186**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGO1	7.0	228	400	170			30				570	0.40	1173		458	1169	244	27.0	142.3	25.1	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Continental Davenport IL(20)
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

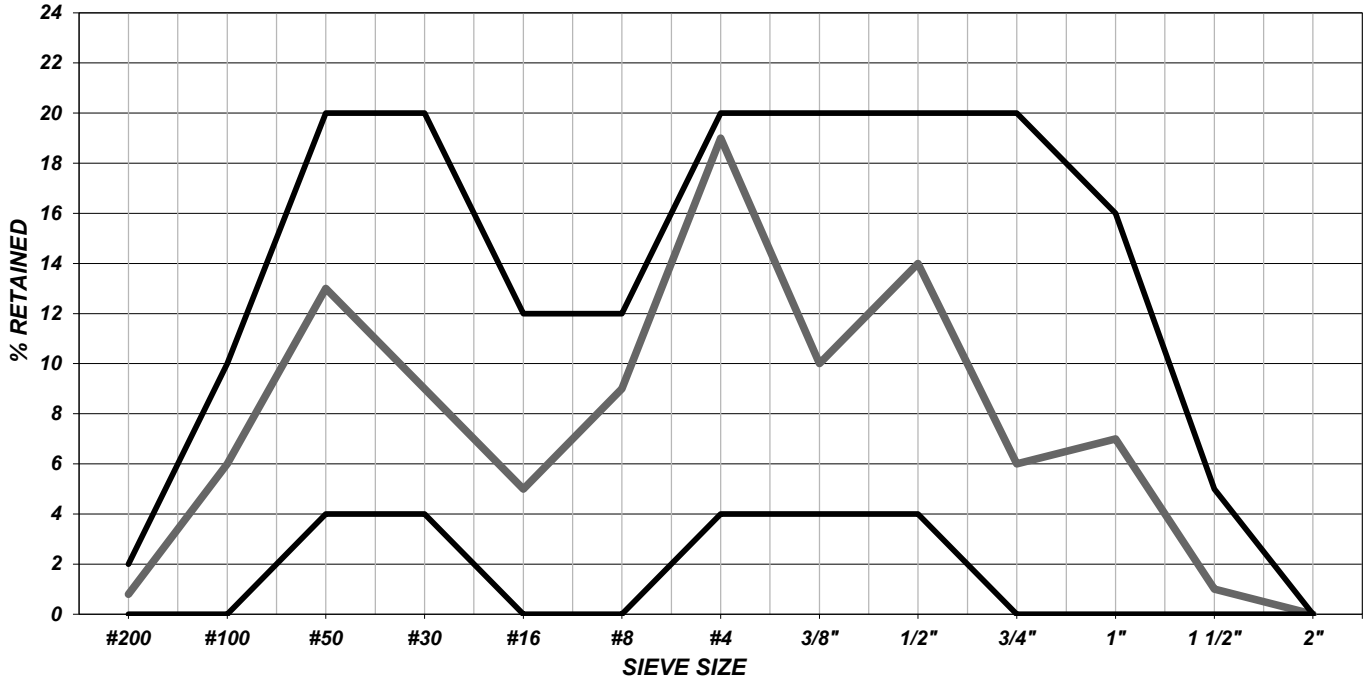
JMF **22-186**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		3/4"+	#67	CIA					
Prop. %	39		15	38	8	**100%**				
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**62**	± 5	57	67	**10**
#4	99.0		0.0	4.1	32.9	**43**	± 5	38	48	**19**
#8	88.2		0.0	0.0	0.8	**34**	± 4	30	38	**9**
#16	74.4		0.0	0.0	0.1	**29**	± 4	25	33	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**9**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGO1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Minnesota Department of Transportation

CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Carbon Limit	CLMLTDZ		2.06
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5	Sika Visocrete 1000	FSIV1000	F	3-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4"+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	220071
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	**22-187**

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													40		15	37	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-RGL1	7.0	228	400			170			30		570	0.40	1186		451	1122	241	27.0	140.7	26.1	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: Carbon Limit Natural Pozzolan and Catalyst
*High range water reducer, Sika Viscocrete 1000, dosage allows 2 to 3 times the control dosage per trial batch report.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

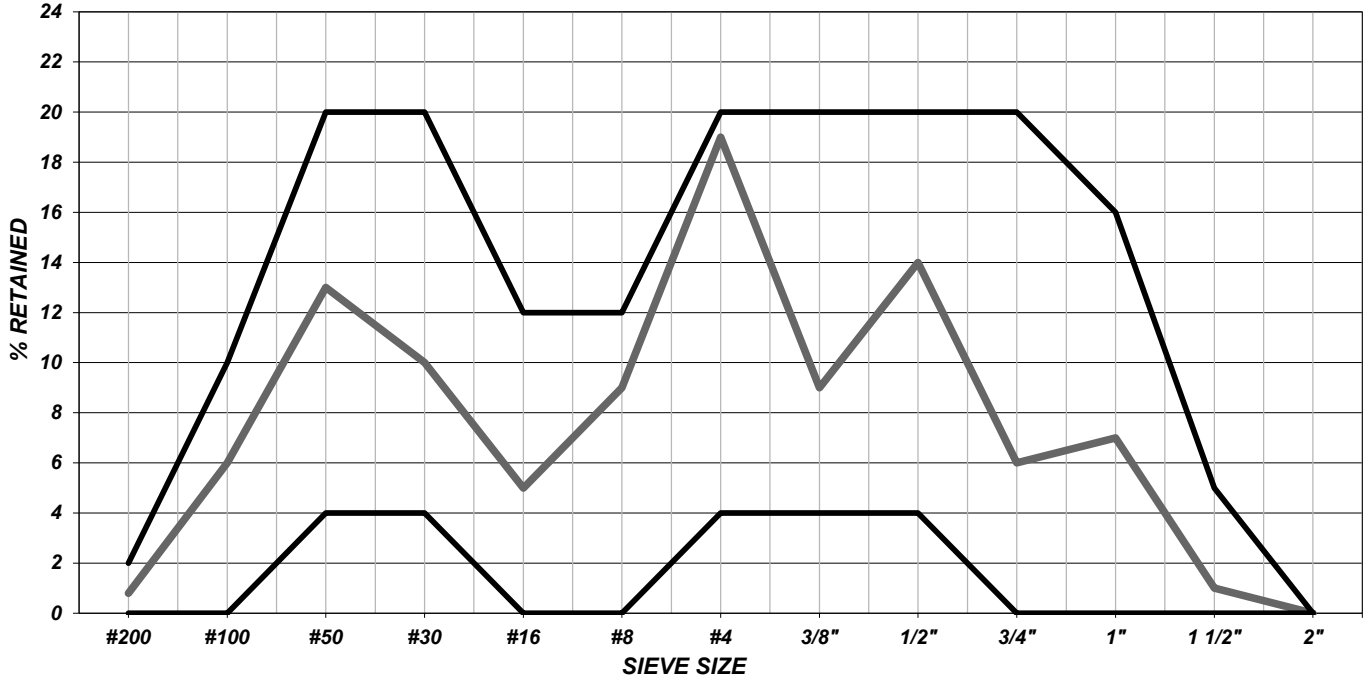
JMF **22-187**

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4"+	#67	CIA					
Prop. %	40		15	37	8	**100%**	**LIMITS**			
2"	100.0		100.0	100.0	100.0	**100**	± 5	95	100	**0**
1 1/2"	100.0		96.1	100.0	100.0	**99**	± 5	94	100	**1**
1"	100.0		45.2	100.0	100.0	**92**	± 5	87	97	**7**
3/4"	100.0		8.5	99.0	100.0	**86**	± 5	81	91	**6**
1/2"	100.0		0.4	64.4	100.0	**72**	± 5	67	77	**14**
3/8"	100.0		0.2	40.4	98.2	**63**	± 5	58	68	**9**
#4	99.0		0.0	4.1	32.9	**44**	± 5	39	49	**19**
#8	88.2		0.0	0.0	0.8	**35**	± 4	31	39	**9**
#16	74.4		0.0	0.0	0.1	**30**	± 4	26	34	**5**
#30	50.7		0.0	0.0	0.0	**20**	± 4	16	24	**10**
#50	17.0		0.0	0.0	0.0	**7**	± 3	4	10	**13**
#100	2.7		0.0	0.0	0.0	**1**	± 2	0	3	**6**
#200	0.4		0.0	0.0	0.0	**0.2**	≤ 1.6	0.0	1.6	**1**

Mix #
3A21-RGL1

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
24
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
30
Between 24-34%, generally enhances workability of the mix.

ECOMATERIAL TECHNOLOGIES

Materials Testing & Research Facility
2650 Old State Hwy 113
Taylorsville, GA 30178
770-684-0102

ASTM C618 / AASHTO M295 Testing of Prairie State Fly Ash

Sample Date: 7/1 - 7/31/22
Report Date: 9/12/2022
Sample Type: Monthly
MTRF ID: 1582PS
Sample ID: MnDOT Split

Chemical Analysis	Results		ASTM Limit Class F / C	AASHTO Limit Class F / C
Silicon Dioxide (SiO2)	55.83	%		
Aluminum Oxide (Al2O3)	18.38	%		
Iron Oxide (Fe2O3)	9.69	%		
Sum (SiO2+Al2O3+Fe2O3)	83.90	%	50.0 min	50.0 min
Sulfur Trioxide (SO3)	1.28	%	5.0 max	5.0 max
Calcium Oxide (CaO)	6.39	%	18.0 max / >18.0	18.0 max / >18.0
Magnesium Oxide (MgO)	1.52	%		
Sodium Oxide (Na2O)	1.27	%		
Potassium Oxide (K2O)	2.71	%		
Total Alkali (Sodium Oxide Equivalent)	3.1	%		
Moisture	0.05	%	3.0 max	3.0 max
Loss on Ignition	0.77	%	6.0 max	5.0 max
Available Alkalies, as Na2Oe	0.81	%	Not Required	1.5 max*
				when required by purchaser
Physical Analysis				
Fineness, % retained on 45-µm sieve	15.56	%	34 max	34 max
Fineness Uniformity	5.0		± 5 max	± 5 max
Strength Activity Index - 7 or 28 day requirement				
7 day, % of control	78	%	75 min	75 min
28 day, % of control	95	%	75 min	75 min
Water Requirement, % control	93	%	105 max	105 max
Autoclave Soundness	-0.05	%	0.8 max	0.8 max
Density	2.37	g/cm3		
Density Uniformity	0.2	%	±5 max	±5 max

The test data listed herein was generated by applicable ASTM methods. The reported results pertain only to the sample(s) or lot(s) tested. This report cannot be reproduced without permission from EM Resources LLC. This material meets the requirements of Florida DOT 929 specification.

Christy Sieg
Lab Manager

AASHTO ACCREDITED

Resource Materials Testing, Inc.

"Specialists in Pozzolan Testing"

24 Fine Drive Murphy, NC 28906 828.361.1114

REPORT OF NATURAL POZZOLAN ANALYSIS

TO: 3M Industrial Mineral Products Division
Attn: John Edwards
3M Center 209-01-W-14
St. Paul, MN 55144

PROJECT NO. RMT-503
SAMPLE NO. 26043
DATE REC.: 09-12-22
DATE REP.: 10-13-22

PROJECT NAME: 3M Natural Pozzolan Quality Assurance Program
SAMPLE ID.: SCM-NP100W GR BH#3 07.13.22

CHEMICAL ANALYSIS:	RESULTS:	ASTM C618 SPEC N
Silicon Dioxide, SiO_2, %	64.41	----
Aluminum Oxide, Al_2O_3, %	17.14	----
Iron Oxide, Fe_2O_3, %	5.74	----
Sum of SiO_2, Al_2O_3 & Fe_2O_3, %	87.29	70.0 Min
Calcium Oxide, CaO, %	2.75	----
Magnesium Oxide, MgO, %	1.88	----
Sodium Oxide, Na_2O, %	2.91	----
Potassium Oxide, K_2O, %	3.84	----
Sulfur Trioxide, SO_3, %	0.02	4.0 Max
Moisture Content, %	0.58	3.0 Max
Loss on Ignition, %	4.11	10.0 Max
Total Alkalis as Na_2O Equivalent, %	5.44	----

PHYSICAL ANALYSIS:	RESULTS:	SPECIFICATION N	
		ASTM C618	AASHTO M295
Amount Retained on No. 325 Sieve, %	6.4	34 Max	
Blaine Fineness, cm^2/g	8,025		
Strength Activity Index			
Portland Cement @ 7 days, % of Control	86	75 Min	
Portland Cement @ 28 days, % of Control	84	75 Min	
Water Requirement, % of Control	98	115 Max	
Autoclave Expansion, %	-0.01	0.8 Max	
Density	2.73	----	

This material meets the requirements of ASTM C 618 and AASHTO M 295 for the parameters tested.

By Robert L Smith
Robert L. Smith, Ph.D.

Trial Batching Report

MnRoad Terra CO2 Final Trial Batching
Terra CO2, Opus

Prepared for

Terra CO2 Technology Holdings, Inc.

Project B2202300
July 14, 2022

Braun Intertec Corporation

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 14, 2022 Project B2202300

Deepak Ravikumar
Terra CO2 Technology Holdings, Inc.
601 16th St., Suite C #324
Golden, CO 80401

Re: MNROAD Final Trial Batching- Opus 35% replacement
Terra CO2 Technology Holding, Inc

Dear Mr. Ravikumar:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. Opus, manufactured by Terra CO2 Technology Holdings, will be used in the pavement of one of the test cells as a 35% replacement of the total cementitious material in the concrete mixture.

A final trail batching was required with test results outlined in table 1 below:

Table 1 .Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions		
Materials	**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL	370	(lbs/yd^3)
Terra CO2, Opus	200	(lbs/yd^3)
Sand - Pit #71041	1183	(lbs/yd^3)
3/4 in + - Pit #19129	462	(lbs/yd^3)
#67 - Pit #71041	1179	(lbs/yd^3)
CIA – Pit #71041	246	(lbs/yd^3)
Water	217	(lbs/yd^3)
Sika Air 260	1.6-1.7*	(oz/cwt)
Sika Visocrete 1000	2.2-2.5*	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	3	2-3/4	2-1/4
Air content (%)	6.2	5.5	6.1
SAM	0.16	0.14	0.25
Unit weight (lbs/yd^3)	147.3		
Box test visual Rating	1	1	1
Box testing slump (inches)	1/2	1/2	1/4

Time of Set		
	Initial (min)	**Final (min)**
Time of Set	438	591

Strength		
Age	**Flexural (psi)**	**Compressive (psi)**
7	505	3140
14	500	3460
28	585	3990
56	TBD	TBD

Note * Air dosage and HRWR may require 1 to 2 time the control mixture.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions:	Dry Weights	
Cement – Holcim St. Genevieve IL	370	(lbs/yd^3)
Terra CO2 Opus	200	(lbs/yd^3)
Sand- Pit #71041	1183	(lbs/yd^3)
¾"+ - Pit #19129	462	(lbs/yd^3)
#67 - Pit #71041	1179	(lbs/yd^3)
CIA – Pit #71041	246	(lbs/yd^3)
Water	217	(lbs/yd^3)
Sika Air 260	1.6-1.7	(oz/cwt)
Sika Visocrete 1000	2.2-2.5	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

The plastic test results are summarized in table 4 below. Tests and specimens required was performed in multiple smaller batches.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump, each side (in)			
1	70	145.5	7.0	2-1/4						
2- Initial	70	147.3	6.2	3	0.16	1	1/2	1/2	1/2	1/2
2- 30 Minutes			5.5	2-3/4	0.14	1	1/2	1/2	1/2	1/2
2- 60 Minutes			6.1	2-1/4	0.25	1	1/4	1/4	1/2	1/4

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age, Days	Modulus of Rupture (psi)
1	7	505
1	14	500
1	28	585
1	56	TBD

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	1380
2	3	2530
2	4	2690
2	7	3140
2	14	3460
2	28	3990
2	56	TBD

The result time of set are presented in table 7 below.

Table 7. Set Time

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	438	591

Additional Note

Admixture dosing notes: Hydration stabilizer and retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between original and double of control mix. Water reducing admixture dosage requirement varied between original and double of control mix.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact Alf Gardiner at 612.682.5125 or AGardiner@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 445815

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Terra CO2 Technology Holdings, Inc.
600 12th St., Suite 130
Golden, CO 80401

Project:
B2202300
Preliminary MnRoad Testing Opus
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	10	**Technician:**	Pomranke, John	**Batched:**	12:00 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	13:10 CDT
Specimens In Set:	21	**Date Cast:**	05/23/22	**Cast:**	13:25 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 35% replacement with timestamp 4/28/2022
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 35% Replacement Batch
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/4 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	68	**Concrete Temp (F):**	68 (ASTM C1064)	**Air Content:**	6.1 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
10-1	1	05/24/22	1 / 0	6.00	28.27	38,253	1,350	5	I	N
10-2	1	05/24/22	1 / 0	6.00	28.27	40,767	1,440	5	I	N
10-3	1	05/24/22	1 / 0	6.00	28.27	37,730	1,340	5	I	N
10-4	3	05/26/22	1 / 2	5.99	28.18	68,766	2,440	5	I	N
10-5	3	05/26/22	1 / 2	5.99	28.18	74,280	2,640	5	I	N
10-6	3	05/26/22	1 / 2	5.99	28.18	71,037	2,520	5	I	N
10-7	4	05/27/22	1 / 3	6.01	28.37	77,885	2,750	5	I	N
10-8	4	05/27/22	1 / 3	6.01	28.37	76,143	2,680	5	I	N
10-9	4	05/27/22	1 / 3	6.01	28.37	75,298	2,650	5	I	N
10-10	7	05/30/22	1 / 6	5.99	28.18	97,782	3,470	1	I	N
10-11	7	05/30/22	1 / 6	5.99	28.18	84,507	3,000	2	I	N
10-12	7	05/30/22	1 / 6	5.99	28.18	83,142	2,950	2	I	N
10-13	14	06/06/22	1 / 13	6.01	28.37	95,594	3,370	5	I	N
10-14	14	06/06/22	1 / 13	6.01	28.37	99,479	3,510	5	I	N
10-15	14	06/06/22	1 / 13	6.01	28.37	99,237	3,500	5	I	N
10-16	28	06/20/22	1 / 27	6.00	28.27	113,281	4,010	5	I	N
10-17	28	06/20/22	1 / 27	6.00	28.27	108,793	3,850	5	I	N
10-18	28	06/20/22	1 / 27	6.00	28.27	116,517	4,120	5	I	N
10-19	56	07/18/22	1 / 55							
10-20	56	07/18/22	1 / 55							
10-21	56	07/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1380**, 3 Day - **2530**, 4 Day - **2690**, 7 Day - **3140**, 14 Day - **3460**, 28 Day - **3990**

I: The result is for informational purposes.
Tested By: Yee Lee (1,2,3,7,8,9,13,14,15), Mitch Kalahar (4,5,6,10,11,12,16,17,18)
Checked In : 05/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)

Capping Methods

N: ASTM C1231, Unbonded Caps

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 445815

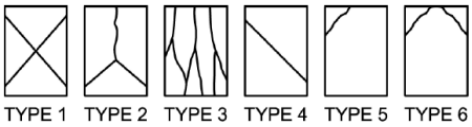
11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:

Terra CO2 Technology Holdings, Inc.
600 12th St., Suite 130
Golden, CO 80401

Project:

B2202300
Preliminary MnRoad Testing Opus
Bloomington Lab
Bloomington, MN 55438



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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/06/2022
Sample: 445813

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Terra CO2 Technology Holdings, Inc.
600 12th St., Suite 130
Golden, CO 80401

Project:
B2202300
Preliminary MnRoad Testing – Opus
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	6	**Technician:**	Pomranke, John	**Batched:**	11:00 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	11:15 CDT
Specimens In Set:	8	**Date Cast:**	05/23/22	**Cast:**	11:30 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 35% replacement with timestamp 4/28/2022
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 35% Replacement Batch
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/4 (ASTM C143)	**Plastic Unit Weight:**	145.5 (lb/ft³) (ASTM C138)
Air Temperature (F):	68	**Concrete Temp (F):**	68 (ASTM C1064)	**Air Content:**	7.0 (ASTM C231)
				Load Volume:	

Standard Cure

Min / Max Temp (F): 68/71

Field Cure

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
6-1	7	05/30/22	1 / 6	6.10	6.00	18	6,012	495	Middle	Wet	I
6-2	7	05/30/22	1 / 6	6.15	6.05	18	6,479	520	Middle	Wet	I
6-3	14	06/06/22	1 / 13	6.20	6.00	18	6,273	505	Middle	Wet	I
6-4	14	06/06/22	1 / 13	6.20	6.00	18	6,075	490	Middle	Wet	I
6-5	28	06/20/22	1 / 27	6.00	6.00	18	7,481	625	Middle	Wet	P
6-6	28	06/20/22	1 / 27	6.15	6.05	18	6,859	550	Middle	Wet	P
6-7	56	07/18/22	1 / 55								
6-8	56	07/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **505**, 14 Day - **500**, 28 Day - **585**

Specimen 6-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 6-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 6-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 6-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 6-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 6-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: John Pomranke (1,2), Yee Lee (3,4), Mitch Kalahar (5,6)

Checked In : 05/24/2022 (1,2,3,4,5,6,7,8)

Signed on Behalf of Katrina Sargent

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2202300

Client:
Terra CO2 Technology Holdings, Inc.
601 16th Street, Suite C #324
Golden, CO 80401

Project Description:
MnRoad Final Trial Batching
Terra CO2 Holdings, Opus

Curve Information

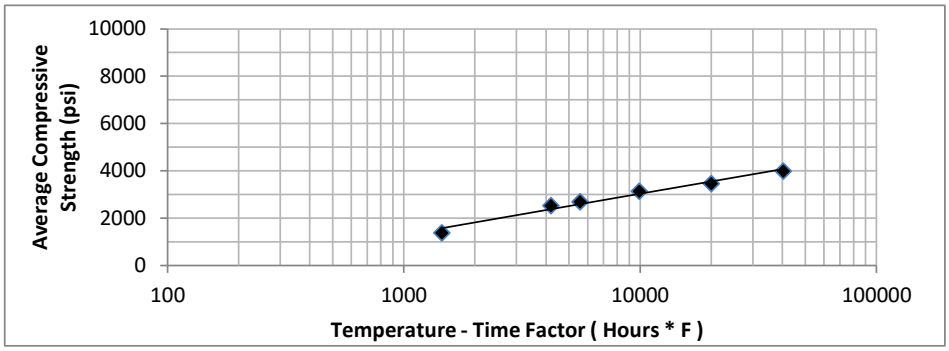
Curve Number:	Opus - 35%	Cast By:	John Pomranke
Cylinder Cast Date:	May 31, 2022		

Specifications and Properties

Mixture Identification:	35% Rep	Specified Strength (psi):	4500
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	2.25	Measured Air Content (%):	6.1
Ambient Temperature (F):	68	Conc. Temperature (F):	71

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1448			1448	1350	1440	1340	1380
3	4195			4195	2440	2640	2520	2530
4	5570			5570	2750	2680	2650	2690
7	9914			9914	3470	3000	2950	3140
14	19973			19973	3370	3510	3500	3460
28	40308			40308	4010	3850	4120	3990



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**752.1** * ln(TTF) +		**-3898.0**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4500**	Required Maturity (Hours *F):		**70691**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Minnesota Department of Transportation CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Terra CO2 Opus			2.58
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	**% Air**	**Water**	**Cement**	**Fly Ash**	**Slag**	**Other CM**	**% Fly Ash**	**% Slag**	**% Other CM**	**% Ternary**	**Total CM**	**W/C Ratio**	**FA#1**	**FA#2**	**CA#1**	**CA#2**	**CA#3**	**Volume**	**Unit Wt.**	**% Paste Volume**	**Slump Range, in**
3A21- Terra CO2	7.0	217	370			200			35		570	0.38	1183		462	1179	246	27.0	142.8	24.6	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

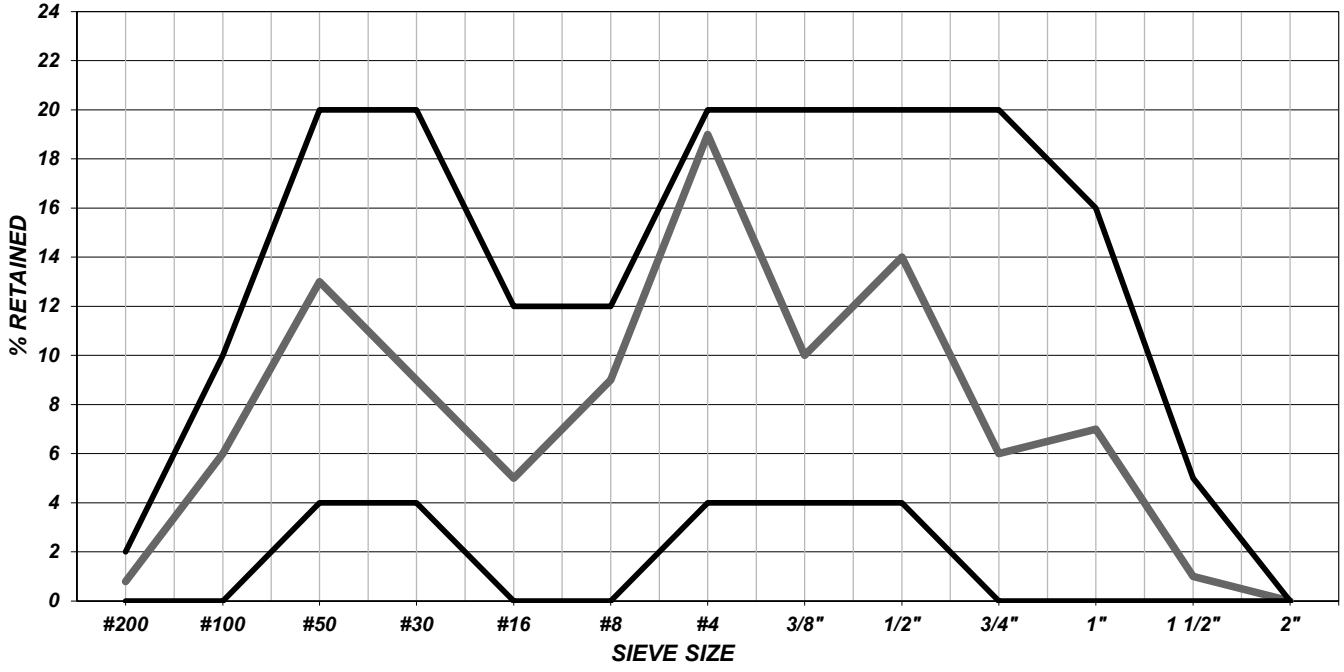
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	38	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	10
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- Terra CO2

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnRoad Final Trial Batching
Ash Grove, LC3 Cement

Prepared for

Ash Grove Cement Company

Project B2202356
July 14, 2022

Braun Intertec Corporation

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 14, 2022 Project B2202356

Cheng Qi
Ash Grove Cement Company
11011 Cody St.
Overland Park, KS 66210

Re: MNROAD Final Trial Batching
Ash Grove Cement Company, LC3 Cement

Dear Mr. Qi:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnRoad.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. LC3 Cement, manufactured by Ash Grove Cement Company, will be used in the pavement of one of the test cells as a replacement of the total cementitious material in the concrete mixture.

A final trail batching was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial Set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions		
Materials	**Oven Dry Weights**	
Ash Grove Cement Company, LC3 Cement	570	(lbs/yd^3)
Sand - Pit #71041	1160	(lbs/yd^3)
3/4 in + - Pit #19129	453	(lbs/yd^3)
#67 - Pit #71041	1187	(lbs/yd^3)
CIA – Pit #71041	211	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	2.5-3.5*	(oz/cwt)
Sika Visocrete 1000	4.5-5.5*	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	2	1	3/4
Air content (%)	7.2	6.0	6.4
SAM	0.39	0.49	0.50
Unit weight (lbs/yd^3)	145.8		
Box test visual Rating	1	2	3
Box testing slump (inches)	1/4	0	0

Time of Set		
	Initial (min)	**Final (min)**
Time of Set	324	419

Strength		
Age	**Flexural (psi)**	**Compressive (psi)**
7	530	4430
14	565	5330
28	690	6060
56	TBD	TBD

Note * Air dosage required 2 to 3 times the control, and the HWRA required 4 to 5 times the control mixture.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions:	Dry Weights	
Cement – Ash Grove Type 1P	570	(lbs/yd^3)
Sand- Pit #71041	1160	(lbs/yd^3)
¾"+ - Pit #19129	453	(lbs/yd^3)
#67 - Pit #71041	1187	(lbs/yd^3)
CIA – Pit #71041	211	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	2.5-3.5	(oz/cwt)
Sika Visocrete 1000	4.5-5.5	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

The plastic test results are summarized in table 4 below. Tests and specimens required was performed in multiple smaller batches.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump, each side (in)			
1	73	145.3	6.9	1-3/4						
2- Initial	69	145.8	7.2	2	0.39	1	1/4	1/4	1/4	¼
2- 30 minutes			6.0	1	0.49	2	0	0	0	1/4
2- 60 minutes			6.4	3/4	0.50	3	0	0	0	0

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age, Days	Average Modulus of Rupture (psi)
1	7	530
1	14	565
1	28	690
1	56	TBD

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	2100
2	3	3380
2	4	3930
2	7	4430
2	14	5330
2	28	6060
2	56	TBD

The result time of set are presented in table 7 below.

Table 7. Set Time

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	324	419

Additional Note

Admixture dosing notes: Retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between double and triple of control mix. Water reducer admixture dosage requirement varied between 4 and 5 times of control mix.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact Alf Gardiner at 612.682.5125 or AGardiner@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/06/2022
Sample: 449173

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Ash Grove Cement Company
11011 Cody Street
Overland Park, KS 66210

Project:
B2202356
MnRoad Ash Grove Cement Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	13:03 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	14:28 CDT
Specimens In Set:	21	**Date Cast:**	06/07/22	**Cast:**	14:38 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Ash Grove Material Type 1P
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Ash Grove Type 1P Replacement
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2 (ASTM C143)	**Plastic Unit Weight:**	145.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	73	**Concrete Temp (F):**	69 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	

Standard Cure	Field Cure
Min / Max Temp (F): 70/73	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	06/08/22	1 / 0	6.00	28.27	61,820	2,110	2	I	N
1-2	1	06/08/22	1 / 0	6.00	28.27	61,827	2,110	5	I	N
1-3	1	06/08/22	1 / 0	6.00	28.27	60,787	2,060	5	I	N
1-4	3	06/10/22	1 / 2	6.01	28.37	94,199	3,320	5	I	N
1-5	3	06/10/22	1 / 2	6.01	28.37	97,706	3,440	5	I	N
1-6	3	06/10/22	1 / 2	6.01	28.37	95,368	3,360	5	I	N
1-7	4	06/11/22	1 / 3	6.00	28.27	114,164	4,040	4	I	N
1-8	4	06/11/22	1 / 3	6.00	28.27	107,338	3,800	5	I	N
1-9	4	06/11/22	1 / 3	6.00	28.27	111,448	3,940	4	I	N
1-10	7	06/14/22	1 / 6	6.00	28.27	119,320	4,220	5	I	N
1-11	7	06/14/22	1 / 6	6.00	28.27	127,470	4,510	5	I	N
1-12	7	06/14/22	1 / 6	6.00	28.27	128,470	4,540	5	I	N
1-13	14	06/21/22	1 / 13	6.01	28.37	146,626	5,170	5	I	N
1-14	14	06/21/22	1 / 13	6.01	28.37	142,281	5,020	5	I	N
1-15	14	06/21/22	1 / 13	6.01	28.37	164,908	5,810	5	I	N
1-16	28	07/05/22	1 / 27	6.01	28.37	181,095	6,380	5	P	N
1-17	28	07/05/22	1 / 27	6.01	28.37	164,138	5,790	5	P	N
1-18	28	07/05/22	1 / 27	6.01	28.37	170,200	6,000	5	P	N
1-19	56	08/02/22	1 / 55							
1-20	56	08/02/22	1 / 55							
1-21	56	08/02/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **2100**, 3 Day - **3380**, 4 Day - **3930**, 7 Day - **4430**, 14 Day - **5330**, 28 Day - **6060**

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The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/06/2022
Sample: 449173

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

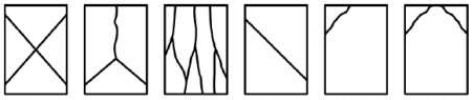
Client:

Ash Grove Cement Company
11011 Cody Street
Overland Park, KS 66210

Project:

B2202356
MnRoad Ash Grove Cement Batching
Bloomington Lab
Bloomington, MN 55438

	Capping Methods
I: The result is for informational purposes. **P:** The result meets or exceeds the compressive strength of the project's specifications. **Tested By:** Mitch Kalahar (1,2,3,10,11,12), Yee Lee (4,5,6,13,14,15,16,17,18), Ryan Kauffman (7,8,9)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/08/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



John Pomranke
07/06/2022

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/06/2022
Sample: 448647

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Ash Grove Cement Company
11011 Cody Street
Overland Park, KS 66210

Project:
B2202356
MnRoad Ash Grove Cement Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	12:50 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	13:15 CDT
Specimens In Set:	8	**Date Cast:**	06/06/22	**Cast:**	13:30 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Ash Grove Material Replacment
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Ash Grove Type 1P Replacement
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-3/4 (ASTM C143)	**Plastic Unit Weight:**	145.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	73	**Concrete Temp (F):**	73 (ASTM C1064)	**Air Content:**	6.9 (ASTM C231)
				Load Volume:	

Standard Cure | **Field Cure**

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	06/13/22	2 / 5	6.15	6.05	18	6,217	495	Middle	Wet	I
1-2	7	06/13/22	2 / 5	6.15	6.05	18	7,015	560	Middle	Wet	I
1-3	14	06/20/22	2 / 12	6.10	6.00	18	7,400	605	Middle	Wet	I
1-4	14	06/20/22	2 / 12	6.15	6.00	18	6,486	525	Middle	Wet	I
1-5	28	07/04/22	2 / 26	6.20	6.05	18	9,148	725	Middle	Wet	P
1-6	28	07/04/22	2 / 26	6.10	6.05	18	8,125	655	Middle	Wet	P
1-7	56	08/01/22	2 / 54								
1-8	56	08/01/22	2 / 54								

Test Age Average Strengths (psi): 7 Day - **530**, 14 Day - **565**, 28 Day - **690**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Yee Lee (1,2), Mitch Kalahar (3,4), John Pomranke (5,6)

Checked In : 06/08/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 13, 2022

Project Number: B2202356

Client:
Cheng Qi
Ash Grove Cement Company
11011 Cody Street
Overland Park, KS 66210

Project Description:
MnRoad Final Batch Testing
Ash Grove Cement Company, LC3

Curve Information

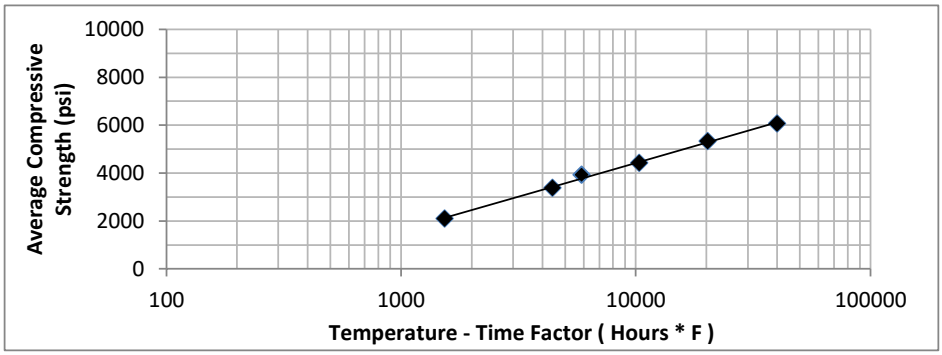
Curve Number: LC3 - 1
Cylinder Cast Date: June 7, 2022
Cast By: John Pomranke

Specifications and Properties

Mixture Identification: Ash Grove LC3
Target Slump (in): 1/2 to 3
Measured Slump (in): 2
Ambient Temperature (F): 70
Specified Strength (psi): 4500
Target Air Content: (%): 5 to 8
Measured Air Content (%): 7.2
Conc. Temperature (F): 69

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1537			1537	2110	2110	2060	2090
3	4420			4420	3320	3440	3360	3370
4	5885			5885	4040	3800	3940	3930
7	10356			10356	4220	4510	4540	4420
14	20266			20266	5170	5020	5810	5330
28	40073			40073	6380	5790	6000	6060



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**1220.9**	* ln(TTF) +	**-6822.7**

Datum Temperature)°F): **14**
Target Field Strength (psi): **4500**
Required Maturity (Hours *F): **10658**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement				3.15
Fly Ash				
Slag				
Other CM	Ash Grove LC3			2.90
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	39	7				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21- LC3	7.0	239				570			100				1160		453	1187	211	27.0		25.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

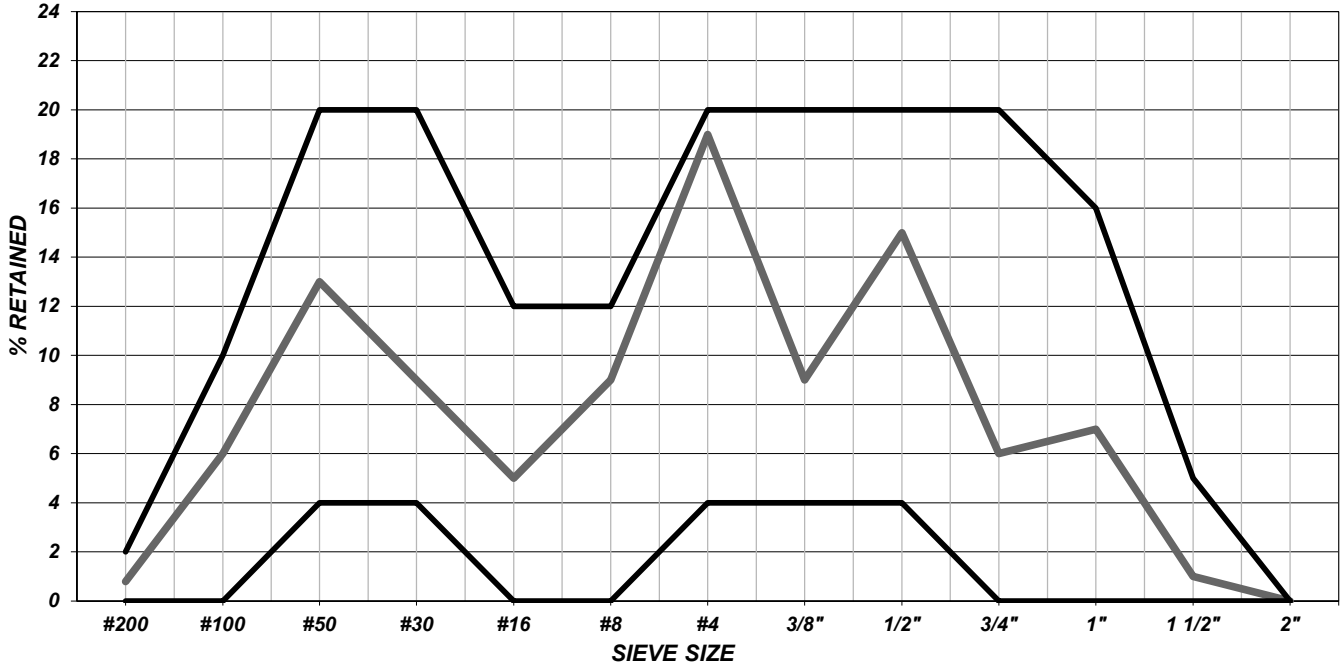
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	39	7	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	71	± 5	66	76	15
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	9
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- LC3

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
Urban Mining Industries, Pozzotive

Prepared for

Urban Mining Industries, LLC

Project B2203878

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 14, 2022 Project B2203878

Dale Hauke
Urban Mining Industries, LLC
270 N. Ave., Suite 200
New Rochelle, NY 10801

Re: MnROAD Trial Batching
Urban Mining Industries, Pozzotive
270 North Avenue, Suite 200
New Rochelle, New York

Dear Mr. Hauke:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. Pozzotive, manufactured by Urban Mining Northeast LLC, will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions			
Materials	**Oven Dry Weights**		
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)	
Urban Mining – Pozzotive	170	(lbs/yd^3)	
Sand - Pit #71041	1183	(lbs/yd^3)	
3/4 in + - Pit #19129	462	(lbs/yd^3)	
#67 - Pit #71041	1179	(lbs/yd^3)	
CIA – Pit #71041	246	(lbs/yd^3)	
Water	217	(lbs/yd^3)	
Sika Air 260*	1.0-3.5	(oz/cwt)	
Sika Visocrete 1000	1.0-1.5	(oz/cwt)	
Sikatard 440	2	(oz/cwt)	
Stabilizer 4R	1	(oz/cwt)	
Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	2	2	1-3/4
Air content (%)	5.3	5.5	5.5
SAM	0.23	0.24	0.3
Unit weight (lbs/yd^3)	147.1	146.2	147.1
Box test visual Rating	1	1	1
Box testing slump (inches)	1/4	1/4	1/4
Time of Set			
	Initial (min)	**Final (min)**	
Time of Set	374	458	
Strength			
Age	**Flexural (psi)**	**Compressive (psi)**	
7	450	3150	
14	560	4550	
28	630	4380	
56	840	TBD	

Note * Air dosage required 1 to 2 time the control mixture.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions	Dry Weights	
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)
Urban Mining – Pozzotive	170	(lbs/yd^3)
Sand - Pit #71041	1183	(lbs/yd^3)
3/4 in + - Pit #19129	462	(lbs/yd^3)
#67 - Pit #71041	1179	(lbs/yd^3)
CIA – Pit #71041	246	(lbs/yd^3)
Water	217	(lbs/yd^3)
Sika Air 260	1.0-3.5	(oz/cwt)
Sika Visocrete 1000	1.0-1.5	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

The plastic test results are summarized in table 4 below. Multiple batches were required to conduct all the testing.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump each side (in)			
1	72	147.3	6.0	2-1/2						
2-Initial	72	147.1	5.3	2	0.23	1	0	1/4	0	0
2- 30 Minutes		146.2	5.4	2	0.24	1	1/4	0	0	1/4
2- 60 Minutes		147.1	5.5	1-3/4	0.3	1	1/4	1/4	1/4	0
3	71	147.4	5.1	1						

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age (days)	Average Modulus of Rupture (psi)
1	7	450
1	14	560
1	28	630
1	56	840

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	1670
2	3	2640
2	4	2730
2	7	3150
3	14	4550
2	28	4380
3	56	TBD

The result time of set are presented in table 7 below.

Table 7. Time of Set

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	374	458

Additional Note

Admixture dosing notes: Water reducer, Hydration stabilizer and retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between original and double of control mix.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/14/2022
Sample: 443393

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Urban Mining Industries, LLC
270 North Ave
Suite 200
New Rochelle, NY 10801

Project:
B2203878
MnROAD Urban Mining Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	10:45 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	12:27 CDT
Specimens In Set:	20	**Date Cast:**	05/12/22	**Cast:**	12:35 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Bloomington Lab
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Pozzotive Replacement 30%
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-3/4 (ASTM C143)	**Plastic Unit Weight:**	147.1 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	72 (ASTM C1064)	**Air Content:**	5.5 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	05/13/22	1 / 0	6.00	28.27	44,659	1,580	5	I	N
1-2	1	05/13/22	1 / 0	6.00	28.27	47,756	1,690	5	I	N
1-3	1	05/13/22	1 / 0	6.00	28.27	48,975	1,730	5	I	N
1-4	3	05/15/22	1 / 2	6.00	28.27	73,013	2,580	4	I	N
1-5	3	05/15/22	1 / 2	6.00	28.27	74,785	2,650	5	I	N
1-6	3	05/15/22	1 / 2	6.00	28.27	76,188	2,700	5	I	N
1-7	4	05/16/22	1 / 3	6.01	28.37	73,111	2,580	5	I	N
1-8	4	05/16/22	1 / 3	6.01	28.37	79,574	2,810	5	I	N
1-9	4	05/16/22	1 / 3	6.01	28.37	79,408	2,800	5	I	N
1-10	7	05/19/22	1 / 6	6.00	28.27	86,197	3,050	5	I	N
1-11	7	05/19/22	1 / 6	6.00	28.27	90,812	3,210	5	I	N
1-12	7	05/19/22	1 / 6	6.00	28.27	90,217	3,190	5	I	N
1-16	28	06/09/22	1 / 27	5.99	28.18	125,477	4,450	5	I	N
1-17	28	06/09/22	1 / 27	5.99	28.18	122,189	4,340	5	I	N
1-18	28	06/09/22	1 / 27	5.99	28.18	122,211	4,340	5	I	N

Test Age Average Strengths (psi): 1 Day - **1670**, 3 Day - **2640**, 4 Day - **2730**, 7 Day - **3150**, 28 Day - **4380**

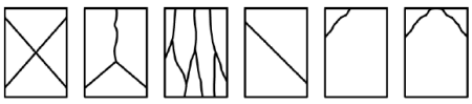
I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2,3,7,8,9,16,17,18), Reid Swanson (4,5,6), Yee Lee (10,11,12)

Checked In : 05/13/2022 (1,2,3,4,5,6,7,8,9,10,11,12,16,17,18)

Capping Methods

N: ASTM C1231, Unbonded Caps



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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 06/22/2022
Sample: 448135

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Urban Mining Industries, LLC
270 North Ave
Suite 200
New Rochelle, NY 10801

Project:
B2203878
MnROAD Urban Mining Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	2	**Technician:**	Pomranke, John	**Batched:**	13:23 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	13:45 CDT
Specimens In Set:	6	**Date Cast:**	06/02/22	**Cast:**	14:00 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Urban Mining Material
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Pozzotive Replacement 30%
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1 (ASTM C143)	**Plastic Unit Weight:**	147.4 (lb/ft³) (ASTM C138)
Air Temperature (F):	73	**Concrete Temp (F):**	71 (ASTM C1064)	**Air Content:**	5.1 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

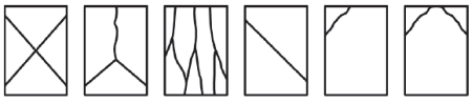
Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
2-1	14	06/16/22	1 / 13	6.00	28.27	115,091	4,070	5	I	N
2-2	14	06/16/22	1 / 13	6.00	28.27	138,405	4,900	5	I	N
2-3	14	06/16/22	1 / 13	6.00	28.27	132,378	4,680	5	I	N
2-4	56	07/28/22	1 / 55							
2-5	56	07/28/22	1 / 55							
2-6	56	07/28/22	1 / 55							

Test Age Average Strengths (psi): 14 Day - **4550**

I: The result is for informational purposes.
Tested By: Mitch Kalahar (1,2,3)
Checked In : 06/03/2022 (1,2,3,4,5,6)

Capping Methods

N: ASTM C1231, Unbonded Caps



John Pomranke
06/22/2022

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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/14/2022
Sample: 443392

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Urban Mining Industries, LLC
270 North Ave
Suite 200
New Rochelle, NY 10801

Project:
B2203878
MnROAD Urban Mining Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	09:55 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	10:30 CDT
Specimens In Set:	8	**Date Cast:**	05/12/22	**Cast:**	10:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Bloomington Lab
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Pozzotive Replacement 30%
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/2 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	72 (ASTM C1064)	**Air Content:**	6.0 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	05/19/22	1 / 6	6.15	6.05	18	5,653	450	Middle	Wet	I
1-2	7	05/19/22	1 / 6	6.10	6.00	18	5,475	450	Middle	Wet	I
1-3	14	05/26/22	1 / 13	6.10	6.05	18	7,063	570	Middle	Wet	I
1-4	14	05/26/22	1 / 13	5.95	6.00	18	6,520	550	Middle	Wet	I
1-5	28	06/09/22	1 / 27	6.20	6.05	18	8,096	640	Middle	Wet	P
1-6	28	06/09/22	1 / 27	6.35	6.05	18	7,996	620	Middle	Wet	P
1-7	56	07/07/22	1 / 55	6.10	6.00	18	9,978	820	Middle	Wet	I
1-8	56	07/07/22	1 / 55	6.15	6.05	18	10,737	860	Middle	Wet	I

Test Age Average Strengths (psi): 7 Day - **450**, 14 Day - **560**, 28 Day - **630**, 56 Day - **840**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-6: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-7: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-8: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Ryan Kauffman (1,2), Mitch Kalahar (3,4,5,6), Yee Lee (7,8)

Checked In : 05/13/2022 (1,2,3,4,5,6,7,8)

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: June 24, 2022

Project Number: B2203878

Client:
Mr. Dale Hauke
Urban Mining Industries, LLC
270 N. Ave. Suite 200
New Rochelle, NY 10801

Project Description:
MnROAD Final Trial Batching
Uban Mining, Pozzotive

Curve Information

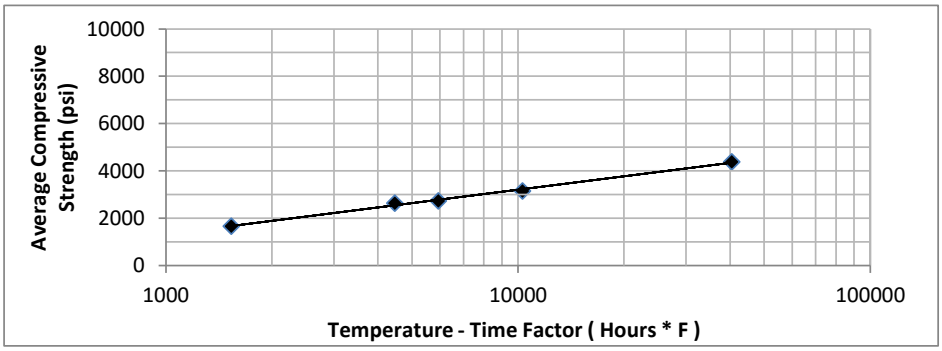
Curve Number: UM 1
Cast By: John Pomranke
Cylinder Cast Date: May 12, 2022

Specifications and Properties

Mixture Identification: Urban Mining
Specified Strength (psi): 4500
Target Slump: (in) 1/2 to 3
Target Air Content: (%) 5 to 8
Measured Slump (in.): 1-3/4
Measured Air Content (% 5.5
Ambient Temperature (F): 70
Conc. Temperature (F): 72

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1532			1532	1580	1690	1730	1670
3	4469			4469	2580	2650	2700	2640
4	5936			5936	2580	2810	2800	2730
7	10282			10282	3050	3210	3190	3150
28	40455			40455	4450	4340	4340	4380



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**816.7**	* ln(TTF) +	**-4317.5**
Datum Temperature)°F):	**14**			
Target Field Strength (psi):	**4500**	Required Maturity (Hours *F):		**48849**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Minnesota Department of Transportation CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Pozzotive			2.51
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	**% Air**	**Water**	**Cement**	**Fly Ash**	**Slag**	**Other CM**	**% Fly Ash**	**% Slag**	**% Other CM**	**% Ternary**	**Total CM**	**W/C Ratio**	**FA#1**	**FA#2**	**CA#1**	**CA#2**	**CA#3**	**Volume**	**Unit Wt.**	**% Paste Volume**	**Slump Range, in**
A21- Urban Minir	7.0	217	400			170			30		570	0.38	1183		462	1179	246	27.0	142.8	24.6	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

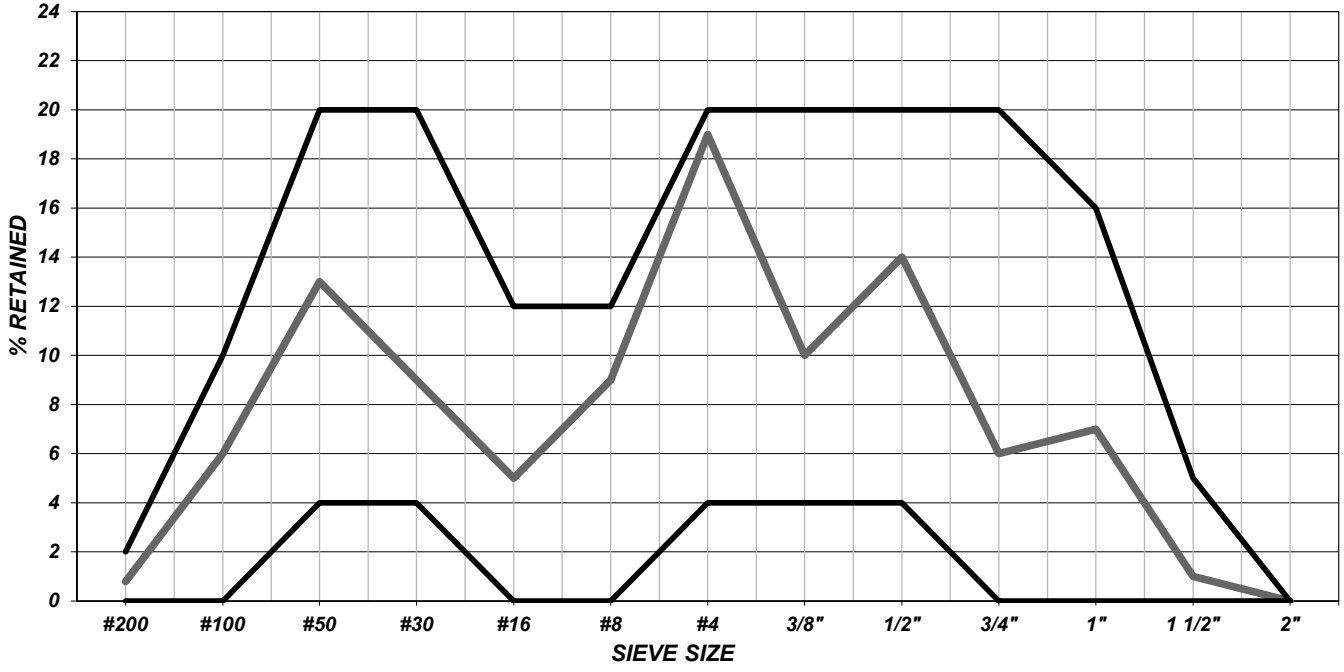
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	38	8	100%				
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	10
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- Urban Mining

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnRoad Final Batching
Burgess Pigment, Optipozz

Prepared for

Burgess Pigment Company

Project B2204164
July 14, 2022

Braun Intertec Corporation

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 14, 2022 Project B2204164

Chris Fagouri
Burgess Pigment Company
525 Beck Blvd.
PO Box 349
Sandersville, GA

Re: MNROAD Final Trial Batching
Burgess Pigment Company, Optipozz

Dear Mr. Fagouri:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnRoad.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. Optipozz , manufactured by Burgess Pigment Company, will be used in the pavement of one of the test cells as a replacement of the cement and fly ash in the concrete mixture.

A final trail batching was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial Set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions		
Materials	**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL	365	(lbs/yd^3)
Fly ash – Boral Coal Creek Class F	136	(lbs/yd^3)
Burgess Pigment – Optipozz	69	(lbs/yd^3)
Sand - Pit #71041	1153	(lbs/yd^3)
3/4 in + - Pit #19129	450	(lbs/yd^3)
#67 - Pit #71041	1149	(lbs/yd^3)
CIA – Pit #71041	240	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	5.5-6.5*	(oz/cwt)
Sika Visocrete 1000	3.5-4.2*	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	1-1/2	1-1/4	1/2
Air content (%)	6.1	5.9	5.5
SAM	0.29	0.21	0.32
Unit weight (lbs/yd^3)	145.5		
Box test visual Rating	1	1	3
Box testing slump (inches)	1/4	0	0

Time of Set		
	Initial (min)	**Final (min)**
Time of Set	335	470

Strength		
Age	**Flexural (psi)**	**Compressive (psi)**
7	620	5100
14	625	5170
28	655	5170
56	TBD	TBD

Note * Air dosage required 5 to 6 time the control mixture. HRWA required 3 to 4 time the dosage of the control .

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions:	Dry Weights	
Cement – Holcim St. Genevieve Type IL	365	(lbs/yd^3)
Fly ash – Boral Coal Creek Class F	136	(lbs/yd^3)
Burgess Pigment – Optipozz	69	(lbs/yd^3)
Sand- Pit #71041	1153	(lbs/yd^3)
¾"+ - Pit #19129	450	(lbs/yd^3)
#67 - Pit #71041	1149	(lbs/yd^3)
CIA – Pit #71041	240	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	5.5-6.5	(oz/cwt)
Sika Visocrete 1000	3.5-4.2	(oz/cwt)
Sikatard 440	2.0	(oz/cwt)
Stabilizer 4R	1.0	(oz/cwt)

The plastic test results are summarized in table 4 below. Tests and specimens required was performed in multiple smaller batches.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump, each side (in)			
1	71	146.7	5.5	1-3/4		1	1/4	1/4	1/4	0
2- Initial	68	145.5	6.1	1-1/2	0.29	1	1/4	1/4	1/4	0
2- 30 Minutes			5.9	1-1/2	0.21	1	0	0	0	0
2- 60 Minutes			5.5	1/2	0.32	3	0	0	0	0

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age, Days	Average Modulus of Rupture (psi)
1	7	620
1	14	625
1	28	655
1	56	

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	2060
2	3	3800
2	4	4220
2	7	5100
2	14	5170
2	28	5170
2	56	

The result time of set are presented in table 7 below.

Table 7. Set Time

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	335	470

Additional Note

Admixture dosing notes: Retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between 5 and 6 times of control mix. Water reducer admixture dosage requirement varied between 3 and 4 times of control mix.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact Alf Gardiner at 612.682.5125 or AGardiner@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/05/2022
Sample: 448276

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Burgess Pigment Co.
525 Beck Blvd
PO Box 349
Sandersville, GA 31082

Project:
B2204164
MnROAD Burgess Pigment Company Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	2	**Technician:**	Pomranke, John	**Batched:**	11:22 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	13:10 CDT
Specimens In Set:	21	**Date Cast:**	06/03/22	**Cast:**	13:20 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location:	Lab Cast
Location Details:	Burgess Pigment Material
Sample Location / Notes:	Bloomington Lab

Batch Log

Supplier:	Bloomington Lab	**Mix Design:**	Burgess Pigment-Metakaolin 12%
On-Site Admixtures:	None		

Specifications

Strength:	4500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-1/2 (ASTM C143)	**Plastic Unit Weight:**	145.5 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	68 (ASTM C1064)	**Air Content:**	6.1 (ASTM C231)
				Load Volume:	

Standard Cure		Field Cure	
Min / Max Temp (F):	70/73		

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
2-1	1	06/04/22	1 / 0	6.00	28.27	63,291	2,240	5	I	N
2-2	1	06/04/22	1 / 0	6.00	28.27	57,445	2,030	5	I	N
2-3	1	06/04/22	1 / 0	6.00	28.27	54,202	1,920	5	I	N
2-4	3	06/06/22	1 / 2	6.01	28.37	109,299	3,850	5	I	N
2-5	3	06/06/22	1 / 2	6.01	28.37	104,540	3,690	5	I	N
2-6	3	06/06/22	1 / 2	6.01	28.37	109,382	3,860	5	I	N
2-7	4	06/07/22	1 / 3	6.00	28.27	118,885	4,210	5	I	N
2-8	4	06/07/22	1 / 3	6.00	28.27	125,296	4,430	5	I	N
2-9	4	06/07/22	1 / 3	6.00	28.27	113,756	4,020	5	I	N
2-10	7	06/10/22	1 / 6	6.01	28.37	142,779	5,030	5	I	N
2-11	7	06/10/22	1 / 6	6.01	28.37	145,917	5,140	5	I	N
2-12	7	06/10/22	1 / 6	6.01	28.37	145,313	5,120	5	I	N
2-13	14	06/17/22	1 / 13	6.01	28.37	138,065	4,870	5	I	N
2-14	14	06/17/22	1 / 13	6.01	28.37	155,538	5,480	5	I	N
2-15	14	06/17/22	1 / 13	6.01	28.37	145,969	5,150	5	I	N
2-16	28	07/01/22	1 / 27	6.00	28.27	145,155	5,140	5	P	N
2-17	28	07/01/22	1 / 27	6.00	28.27	141,851	5,020	5	P	N
2-18	28	07/01/22	1 / 27	6.00	28.27	151,664	5,370	5	P	N
2-19	56	07/29/22	1 / 55							
2-20	56	07/29/22	1 / 55							
2-21	56	07/29/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **2060**, 3 Day - **3800**, 4 Day - **4220**, 7 Day - **5100**, 14 Day - **5170**, 28 Day - **5170**

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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/05/2022
Sample: 448276

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

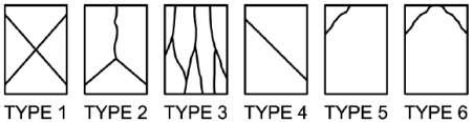
Client:

Burgess Pigment Co.
525 Beck Blvd
PO Box 349
Sandersville, GA 31082

Project:

B2204164
MnROAD Burgess Pigment Company Batching
Bloomington Lab
Bloomington, MN 55438

	Capping Methods
I: The result is for informational purposes. **P:** The result meets or exceeds the compressive strength of the project's specifications. **Tested By:** Mitch Kalahar (1,2,3,7,8,9,16,17,18), Yee Lee (4,5,6,10,11,12,13,14,15)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/04/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



John Pomranke
07/05/2022

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/05/2022
Sample: 447866

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Burgess Pigment Co.
525 Beck Blvd
PO Box 349
Sandersville, GA 31082

Project:
B2204164
MnROAD Burgess Pigment Company Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	13:00 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	13:30 CDT
Specimens In Set:	8	**Date Cast:**	06/01/22	**Cast:**	13:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: Final Batch
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: Burgess Pigment-Metakaolin 12%
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-3/4 (ASTM C143)	**Plastic Unit Weight:**	146.7 (lb/ft³) (ASTM C138)
Air Temperature (F):	70	**Concrete Temp (F):**	71 (ASTM C1064)	**Air Content:**	5.5 (ASTM C231)
				Load Volume:	

Standard Cure

Min / Max Temp (F): 70/73

Field Cure

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	06/08/22	1 / 6	6.10	5.95	18	8,062	670	Middle	Wet	I
1-2	7	06/08/22	1 / 6	6.20	5.95	18	6,935	570	Middle	Wet	I
1-3	14	06/15/22	1 / 13	6.15	6.05	18	7,840	625	Middle	Wet	I
1-4	14	06/15/22	1 / 13	6.10	6.05	18	7,690	620	Middle	Wet	I
1-5	29	06/30/22	1 / 28	6.25	6.00	18	8,385	670	Middle	Wet	P
1-6	29	06/30/22	1 / 28	6.25	6.00	18	8,034	645	Middle	Wet	P
1-7	56	07/27/22	1 / 55								
1-8	56	07/27/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **620**, 14 Day - **625**, 29 Day - **655**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Yee Lee (1,2), Ryan Kauffman (3,4), Mitch Kalahar (5,6)

Checked In : 06/02/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 14, 2022

Project Number: B2204164

Client:
Mr. Chris Fagouri
Burgess Pigment Company
525 Beck Blvd PO Box 349
Sandersville, GA 31082

Project Description:
MnRoad Final Batching
Burgess Pigment Company, Optipozz

Curve Information

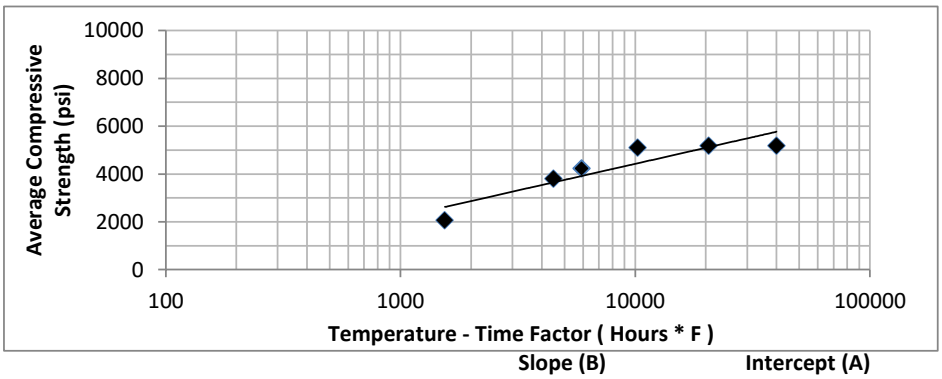
Curve Number: MET-1
Cylinder Cast Date: June 3, 2022
Cast By: John Pomranke

Specifications and Properties

Mixture Identification:	Metakaolin 12%	Specified Strength (psi):	4500
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	1-1/2	Measured Air Content (%):	6.1
Ambient Temperature (F):	68	Conc. Temperature (F):	68

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1544			1544	2240	2030	1920	2060
3	4483			4483	3850	3690	3860	3800
4	5910			5910	4210	4430	4020	4220
7	10242			10242	5030	5140	5120	5100
14	20572			20572	4870	5480	5150	5170
28	40036			40036	5140	5020	5370	5180



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**967.1**	* ln(TTF) +	**-4480.7**

Datum Temperature (F): **14**
Target Field Strength (psi): **4500**
Required Maturity (Hours *F): **10788**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Minnesota Department of Transportation CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash	Boral Coal Creek	COCUNND	F	2.50
Slag				
Other CM	urgess Pigment- OPTIPOZ			2.20
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	**% Air**	**Water**	**Cement**	**Fly Ash**	**Slag**	**Other CM**	**% Fly Ash**	**% Slag**	**% Other CM**	**% Ternary**	**Total CM**	**W/C Ratio**	**FA#1**	**FA#2**	**CA#1**	**CA#2**	**CA#3**	**Volume**	**Unit Wt.**	**% Paste Volume**	**Slump Range, in**
3A21- Burgess	7.0	239	365	136		69	24		12	36	570	0.42	1153		450	1149	240	27.0	140.8	26.3	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

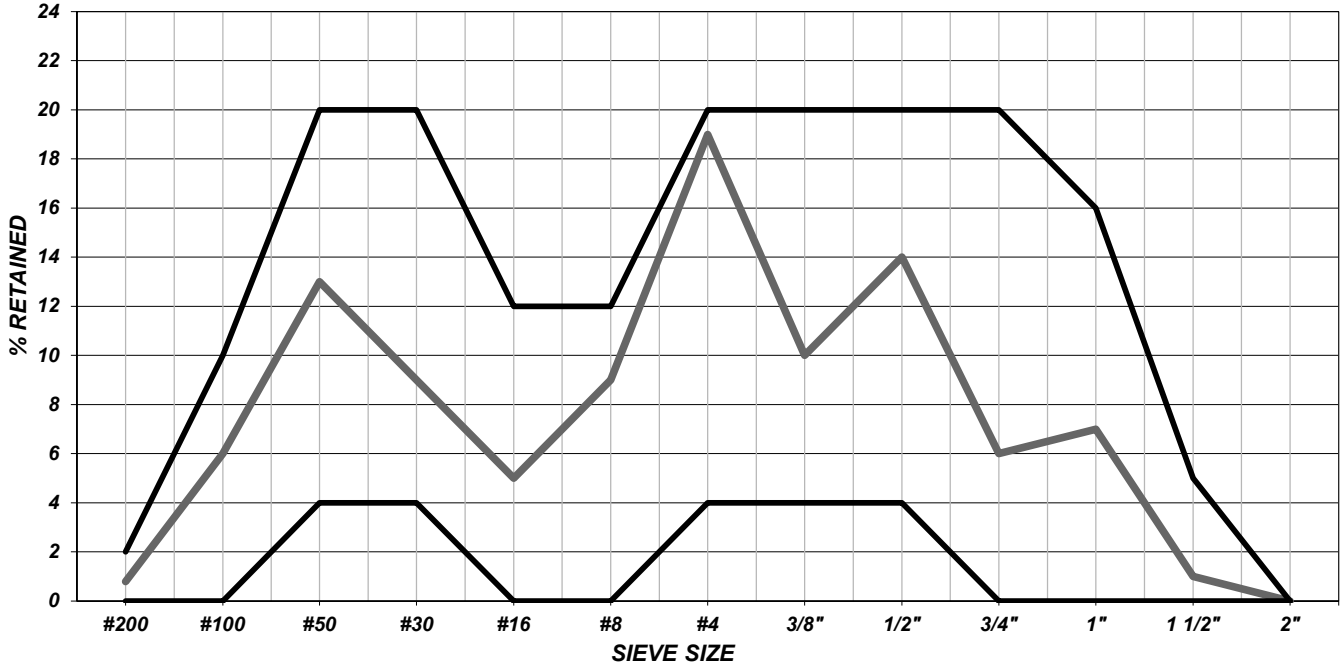
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	38	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	10
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- Burgess

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
Carbon Upcycling Technologies

Prepared for

Carbon Upcycling Technologies

Project B2204792
July 26, 2022

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 26, 2022 Project B2204792

Ms. Natalie Giglio
Carbon Upcycling Technologies
9550 100th St. SE
Calgary, AB T3S 0A2
Canada

Re: MnROAD Trial Batching
Carbon Limit

Dear Mr. Pedroza:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. A Pozzolan, manufactured by Carbon Upcycling Technologies will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions			
Materials		**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL		350	(lbs/yd^3)
Carbon Limit		150	(lbs/yd^3)
Sand - Pit #71041		1298	(lbs/yd^3)
3/4 in + - Pit #19129		450	(lbs/yd^3)
#67 - Pit #71041		1198	(lbs/yd^3)
CIA – Pit #71041		257	(lbs/yd^3)
Water		200	(lbs/yd^3)
Sika Air 260		3	(oz/cwt)
Sika Visocrete 1000		0.2	(oz/cwt)
Sikatard 440		2	(oz/cwt)
Stabilizer 4R		1	(oz/cwt)
Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	3	3-1/4	2-1/2
Air content (%)	5.5	5.8	5.7
SAM	N/A	0.46	0.47
Unit weight (lbs/yd^3)	146.8		
Box test visual Rating	1	1	1
Box testing slump (inches)	1/4	1/4	1/4
Time of Set			
	Initial (min)	**Final (min)**	
Time of Set	322	433	
Strength			
Age	**Flexural (psi)**	**Compressive (psi)**	
7	430		
14	TBD		
28	TBD		
56	TBD		

Note * Air dosage required 2 times the control mixture. HRWA required 20% of the dosage for the control.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions	Dry Weights	
Cement – Holcim St. Genevieve IL	350	(lbs/yd^3)
Hess Natural Pozzolan	150	(lbs/yd^3)
Sand - Pit #71041	1298	(lbs/yd^3)
3/4 in + - Pit #19129	450	(lbs/yd^3)
#67 - Pit #71041	1198	(lbs/yd^3)
CIA – Pit #71041	257	(lbs/yd^3)
Water	200	(lbs/yd^3)
Sika Air 260	3	(oz/cwt)
Sika Visocrete 1000	0.2	(oz/cwt)
Sikatard 440	2	(oz/cwt)
Stabilizer 4R	1	(oz/cwt)

The plastic test results are summarized in table 4 below. Multiple batches were required to conduct all the testing.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump each side (in)			
1	72	145.9	6.0	2-1/2						
2-Initial	70.5	146.8	5.5	3	N/A*	1	1/4	1/4	1/4	3/8
2- 30 Minutes			5.8	3-1/4	0.46	1	1/4	1/4	1/4	1/4
2- 60 Minutes			5.7	2-1/2	0.47	1	1/4	1/4	1/4	1/4

Note * Did not compute

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age (days)	Average Modulus of Rupture (psi)
1	7	430
1	14	TBD
1	28	TBD
1	56	TBD

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	1320
2	3	2200
2	4	TBD
2	7	TBD
3	14	TBD
2	28	TBD
3	56	TBD

The result time of set are presented in table 7 below.

Table 7. Time of Set

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	322	433

Additional Note

Admixture dosing notes:. Air entraining admixture dosage requirement is 2 times the dose of control mix. It may be advantageous to batch the first truck without water reducer.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/26/2022
Sample: 460801

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Carbon Upcycling Technologies
9550 100th St SE
Calgary, AB T3S 0A2

Project:
B2204792
Carbon Upcycling MnROAD
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	3	**Technician:**	Pomranke, John	**Batched:**	12:25 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	13:30 CDT
Specimens In Set:	21	**Date Cast:**	07/19/22	**Cast:**	13:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement of Carbon Upcycling material, 500 lbs cementitious material
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% replacement with Carbon Upcycling Material at 500 lbs cementitious
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)

Field Measurements

Weather:		**Slump (in):**	2-1/2 (ASTM C143)	**Plastic Unit Weight:**	146.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	70	**Concrete Temp (F):**	71 (ASTM C1064)	**Air Content:**	5.7 (ASTM C231)
				Load Volume:	

Standard Cure

Min / Max Temp (F): 70/73

Field Cure

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
3-1	1	07/20/22	1 / 0	6.01	28.37	34,588	1,220	5	I	N
3-2	1	07/20/22	1 / 0	6.01	28.37	39,313	1,390	2	I	N
3-3	1	07/20/22	1 / 0	6.01	28.37	38,798	1,370	2	I	N
3-4	3	07/22/22	1 / 2	5.99	28.18	64,052	2,270	5	I	N
3-5	3	07/22/22	1 / 2	5.99	28.18	61,805	2,190	5	I	N
3-6	3	07/22/22	1 / 2	5.99	28.18	60,447	2,150	5	I	N
3-7	4	07/23/22	1 / 3							
3-8	4	07/23/22	1 / 3							
3-9	4	07/23/22	1 / 3							
3-10	7	07/26/22	1 / 6							
3-11	7	07/26/22	1 / 6							
3-12	7	07/26/22	1 / 6							
3-13	14	08/02/22	1 / 13							
3-14	14	08/02/22	1 / 13							
3-15	14	08/02/22	1 / 13							
3-16	28	08/16/22	1 / 27							
3-17	28	08/16/22	1 / 27							
3-18	28	08/16/22	1 / 27							
3-19	56	09/13/22	1 / 55							
3-20	56	09/13/22	1 / 55							
3-21	56	09/13/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1320**, 3 Day - **2200**

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/26/2022
Sample: 460801

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

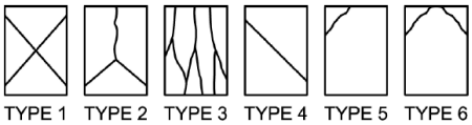
Client:

Carbon Upcycling Technologies
9550 100th St SE
Calgary, AB T3S 0A2

Project:

B2204792
Carbon Upcycling MnROAD
Bloomington Lab
Bloomington, MN 55438

	Capping Methods
I: The result is for informational purposes. **Tested By:** Yee Lee (1), Mitch Kalahar (2,3,4,5,6)	**N:** ASTM C1231, Unbonded Caps
Checked In : 07/20/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/26/2022
Sample: 459416

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Carbon Upcycling Technologies
9550 100th St SE
Calgary, AB T3S 0A2

Project:
B2204792
Carbon Upcycling MnROAD
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	3	**Technician:**	Pomranke, John	**Batched:**	10:00 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	10:30 CDT
Specimens In Set:	8	**Date Cast:**	07/14/22	**Cast:**	10:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement with Carbon Upcycling Material at 500 lbs cementitious
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% replacement with Carbon Upcycling Material at 500 lbs cementitious
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/2 (ASTM C143)	**Plastic Unit Weight:**	145.9 (lb/ft³) (ASTM C138)
Air Temperature (F):	71	**Concrete Temp (F):**	72 (ASTM C1064)	**Air Content:**	6.0 (ASTM C231)
				Load Volume:	

Standard Cure

Min / Max Temp (F): 70/73

Field Cure

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
3-1	7	07/21/22	1 / 6	6.05	5.95	18	4,767	400	Middle	Wet	I
3-2	7	07/21/22	1 / 6	6.20	6.05	18	5,730	455	Middle	Wet	I
3-3	14	07/28/22	1 / 13								
3-4	14	07/28/22	1 / 13								
3-5	28	08/11/22	1 / 27								
3-6	28	08/11/22	1 / 27								
3-7	56	09/08/22	1 / 55								
3-8	56	09/08/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **430**

Specimen 3-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-2: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Ryan Kauffman (1,2)

Checked In : 07/15/2022 (1,2,3,4,5,6,7,8)

Minnesota Department of Transportation (12/6/19)

Project Specific Structural Concrete Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Carbon upcycling Materia			2.55
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Fiber				

Use for:
High Performance Bridge
Mass Concrete
Self Consolidating Concrete (SCC)
Specialty Concrete

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume							
													41		14	37	8			
Mix #	**% Air**	**Water**	**Cement**	**Fly Ash**	**Slag**	**Other CM**	**% Fly Ash**	**% Slag**	**% Other CM**	**% Ternary**	**Total CM**	**W/C Ratio**	**FA#1**	**FA#2**	**CA#1**	**CA#2**	**CA#3**	**Volume**	**Unit Wt.**	**% Paste Volume**
21- Carbon Upcyc	6.5	200	350			150			30		500	0.40	1298		450	1198	257	27.0	144.5	22.1

Slump Range, in	Spread Range if using SCC, in	Anticipated Strength, psi
1/2-3		4500

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

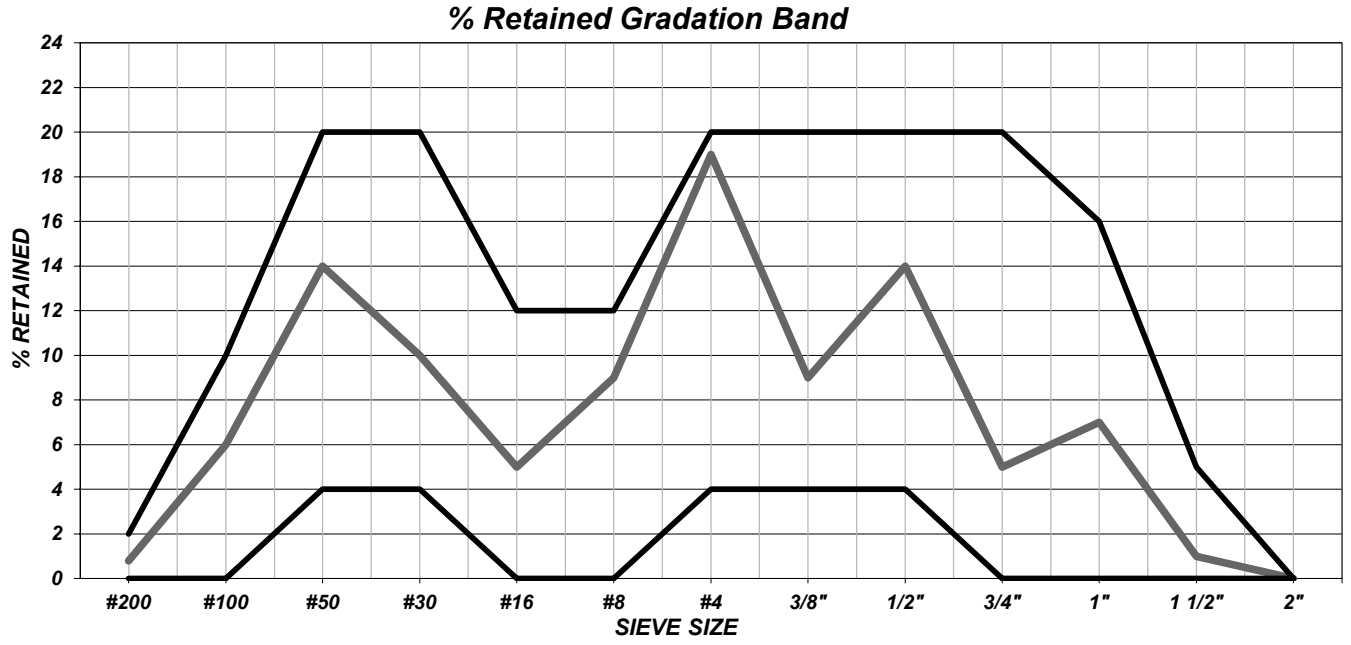
Contractor Mix Design - Job Mix Formula (JMF)

JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	41		14	37	8	100%				
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	87	± 5	82	92	5
1/2"	100.0		0.4	64.4	100.0	73	± 5	68	78	14
3/8"	100.0		0.2	40.4	98.2	64	± 5	59	69	9
#4	99.0		0.0	4.1	32.9	45	± 5	40	50	19
#8	88.2			0.0	0.8	36	± 4	32	40	9
#16	74.4				0.1	31	± 4	27	35	5
#30	50.7					21	± 4	17	25	10
#50	17.0					7	± 3	4	10	14
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- Carbon Upcycling



Coarse Sand % Retained (#8 through #30)
24
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
31
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
CarbonCure

Prepared for

CarbonCure Technologies

Project B2205765
July 27, 2022

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 27, 2022 Project B2205156

Ms. Shannon Seipel
CarbonCure Technologies
42 Payzant Ave.
Dartmouth, NS B3B 1Z6
Canada

Re: MnROAD Trial Batching
CarbonCure Technologies

Dear Ms. Seipel:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. CarbonCure, will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Testing Summary and Results

Plastic testing was performed at Cemstone Ready-mix batch plant along with casting of specimens for strength testing. The specimens were then transported to our Bloomington laboratory for testing. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Additional Note

Additional ages for compressive strength were conducted and presented in the attachments. The 60-minute test data was not conducted due to timing of the truck batches and adjustments to the load.

Table 2. Data Summary

Proportions				
Materials / Mix Designs (Oven Dry Weights)	**3A21-PCC01**	**3A21-PCC03**	**3A21-PCC04**	**3A21-PCC05**
Continental Davenport, (lbs/yd3)	399	387	399	387
Coal Creek, (lbs/yd^3)	171	166	171	166
Sand - Pit #71002, (lbs/yd^3)	1367	1374	1367	1374
# 67- Pit #71002, (lbs/yd^3)	1295	1301	1295	1301
3/4 + - Pit # 71002, (lbs/yd^3)	393	395	393	395
Water, (lbs/yd^3)	228	228	225	228
MBS Miro Air90, (oz/cwt)	0.1-10	0.1-11	0.1-12	0.1-13
MBS Polyhee 1020 , (oz/cwt)	1-12	1-13	1-14	1-15
MBS, Master Matrix 358, (oz/cwt)	0-6	0-6	0-6	0-6
MBS, Master Set Delvo, (oz/cwt)	0-3	0-3	0-3	0-3
MBS, MasterSure Z 60 (oz/cwt)	0-12	0-12	0-12	0-12
CarbonCure	0	6.0	6.0	0

Plastic Testing								
Test	**Initial**	**30 Mins**	**Initial**	**30 Mins**	**Initial**	**30 Mins**	**Initial**	**30 Mins**
Slump (inches)	**2**	**1.75**	**3.5**	**1.75**	**3**	**2.5**	**3**	**1.5**
Air content (%)	**7.2**	**6.81**	**7.8**	**6.8**	**8.8**	**7.5**	**8.6**	**6.9**
SAM	**0.16**	**0.17**	**0.14**	**0.26**	**0.26**	**N/A**	**0.13**	**0.19**
Box test visual rating	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**0**
Box test slump (inches)	**5/16**	**1/8**	**1/16**	**1/16**	**1/8**	**1/4**	**1/4**	**1/16**
Unit weight	**145.3**		**144.4**		**147.3**		**142.6**	
Time of set - Initial (min)	**218**		**258**		**268**		**233**	
Time of set - Final (min)	**296**		**362**		**355**		**330**	

Strength								
Age (Days)	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**
7	485	3210	485	2600	510	2970	450	2540
14	545	3870	530	3280	580	3850	525	3010
28	575	4400	550	3980	730	4300	625	3750

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453800

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	1	**Technician:**	Koran, Ronald	**Batched:**	09:11 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	09:36 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	09:48 CDT
Truck / Ticket #:	996 / 5703065	**Sampled From:**	Chute	**Truck Empty:**	10:11 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC01
Plant:	16 Dayton, MN		
Sample Condition:			
On-Site Admixtures:	None		

Specifications

Strength:	4000 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	2 (ASTM C143)	**Plastic Unit Weight:**	147.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	3.00 (yd³)

Standard Cure	Field Cure
Min / Max Temp (F): /95	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	06/24/22	1 / 0	6.01	28.37	51,728	1,820	5	I	N
1-2	1	06/24/22	1 / 0	6.01	28.37	53,870	1,900	5	I	N
1-3	1	06/24/22	1 / 0	6.01	28.37	47,779	1,680	5	I	N
1-4	3	06/26/22	1 / 2	6.00	28.27	65,757	2,330	5	I	N
1-5	3	06/26/22	1 / 2	6.00	28.27	72,839	2,580	5	I	N
1-6	3	06/26/22	1 / 2	6.00	28.27	64,618	2,290	4	I	N
1-7	4	06/27/22	1 / 3	6.00	28.27	79,363	2,810	5	I	N
1-8	4	06/27/22	1 / 3	6.00	28.27	76,128	2,690	5	I	N
1-9	4	06/27/22	1 / 3	6.00	28.27	80,148	2,840	5	I	N
1-10	7	06/30/22	1 / 6	6.00	28.27	89,968	3,180	5	I	N
1-11	7	06/30/22	1 / 6	6.00	28.27	90,058	3,190	5	I	N
1-12	7	06/30/22	1 / 6	6.00	28.27	92,336	3,270	5	I	N
1-13	14	07/07/22	1 / 13	6.02	28.46	110,159	3,870	5	I	N
1-14	14	07/07/22	1 / 13	6.02	28.46	109,676	3,850	5	I	N
1-15	14	07/07/22	1 / 13	6.02	28.46	110,671	3,890	5	I	N
1-16	28	07/21/22	1 / 27	6.01	28.37	128,841	4,540	5	P	N
1-17	28	07/21/22	1 / 27	6.01	28.37	125,447	4,420	5	P	N
1-18	28	07/21/22	1 / 27	6.01	28.37	120,228	4,240	5	P	N
1-19	56	08/18/22	1 / 55							
1-20	56	08/18/22	1 / 55							
1-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1800**, 3 Day - **2400**, 4 Day - **2780**, 7 Day - **3210**, 14 Day - **3870**, 28 Day - **4400**

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453800

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

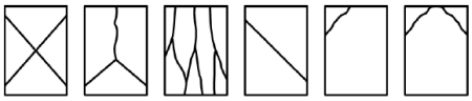
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **P:** The result meets or exceeds the compressive strength of the project's specifications. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15,16,17,18)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453805

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	2	**Technician:**	Koran, Ronald	**Batched:**	10:27 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	10:52 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	11:07 CDT
Truck / Ticket #:	996 / 5703315	**Sampled From:**	Chute	**Truck Empty:**	11:27 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier: Cemstone Products Co.
Plant: 16 Dayton, MN
Mix Design: 3A21-PCC04
Sample Condition:
On-Site Admixtures: None

Specifications

Strength: 4000 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	76 (ASTM C1064)	**Air Content:**	7.5 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
2-1	1	06/24/22	1 / 0	6.01	28.37	44,727	1,580	5	I	N
2-2	1	06/24/22	1 / 0	6.01	28.37	47,627	1,680	5	I	N
2-3	1	06/24/22	1 / 0	6.01	28.37	49,339	1,740	5	I	N
2-4	3	06/26/22	1 / 2	6.00	28.27	66,677	2,360	6	I	N
2-5	3	06/26/22	1 / 2	6.00	28.27	56,676	2,010	6	I	N
2-6	3	06/26/22	1 / 2	6.00	28.27	61,797	2,190	5	I	N
2-7	4	06/27/22	1 / 3	6.00	28.27	73,699	2,610	5	I	N
2-8	4	06/27/22	1 / 3	6.00	28.27	75,223	2,660	5	I	N
2-9	4	06/27/22	1 / 3	6.00	28.27	68,072	2,410	5	I	N
2-10	7	06/30/22	1 / 6	6.00	28.27	89,078	3,150	5	I	N
2-11	7	06/30/22	1 / 6	6.00	28.27	86,121	3,050	5	I	N
2-12	7	06/30/22	1 / 6	6.00	28.27	76,475	2,710	5	I	N
2-13	14	07/07/22	1 / 13	6.02	28.46	114,111	4,010	5	I	N
2-14	14	07/07/22	1 / 13	6.02	28.46	111,154	3,910	5	I	N
2-15	14	07/07/22	1 / 13	6.02	28.46	103,740	3,650	5	I	N
2-16	28	07/21/22	1 / 27	6.01	28.37	124,670	4,390	5	P	N
2-17	28	07/21/22	1 / 27	6.01	28.37	118,689	4,180	5	P	N
2-18	28	07/21/22	1 / 27	6.01	28.37	122,830	4,330	5	P	N
2-19	56	08/18/22	1 / 55							
2-20	56	08/18/22	1 / 55							
2-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1670**, 3 Day - **2180**, 4 Day - **2560**, 7 Day - **2970**, 14 Day - **3850**, 28 Day - **4300**

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The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453805

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

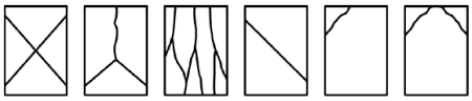
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **P:** The result meets or exceeds the compressive strength of the project's specifications. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15,16,17,18)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453806

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	3	**Technician:**	Koran, Ronald	**Batched:**	11:49 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	12:14 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	12:26 CDT
Truck / Ticket #:	713 / 5703534	**Sampled From:**	Chute	**Truck Empty:**	12:49 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier: Cemstone Products Co.
Plant: 16 Dayton, MN
Sample Condition:
On-Site Admixtures: None
Mix Design: 3A21-PCC05

Specifications

Strength: 4000 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	142.6 (lb/ft³) (ASTM C138)
Air Temperature (F):	88	**Concrete Temp (F):**	82 (ASTM C1064)	**Air Content:**	8.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
3-1	1	06/24/22	1 / 0	6.01	28.37	40,116	1,410	5	I	N
3-2	1	06/24/22	1 / 0	6.01	28.37	39,283	1,390	5	I	N
3-3	1	06/24/22	1 / 0	6.01	28.37	37,791	1,330	5	I	N
3-4	3	06/26/22	1 / 2	6.00	28.27	56,842	2,010	5	I	N
3-5	3	06/26/22	1 / 2	6.00	28.27	49,604	1,760	5	I	N
3-6	3	06/26/22	1 / 2	6.00	28.27	54,451	1,930	5	I	N
3-7	4	06/27/22	1 / 3	6.00	28.27	62,567	2,210	2	I	N
3-8	4	06/27/22	1 / 3	6.00	28.27	58,652	2,080	5	I	N
3-9	4	06/27/22	1 / 3	6.00	28.27	59,587	2,110	5	I	N
3-10	7	06/30/22	1 / 6	6.00	28.27	66,292	2,350	5	I	N
3-11	7	06/30/22	1 / 6	6.00	28.27	74,174	2,620	5	I	N
3-12	7	06/30/22	1 / 6	6.00	28.27	74,551	2,640	5	I	N
3-13	14	07/07/22	1 / 13	6.02	28.46	89,304	3,140	5	I	N
3-14	14	07/07/22	1 / 13	6.02	28.46	79,695	2,800	5	I	N
3-15	14	07/07/22	1 / 13	6.02	28.46	87,532	3,080	5	I	N
3-16	28	07/21/22	1 / 27	6.01	28.37	100,429	3,540	5	I	N
3-17	28	07/21/22	1 / 27	6.01	28.37	109,276	3,850	5	I	N
3-18	28	07/21/22	1 / 27	6.01	28.37	109,487	3,860	5	I	N
3-19	56	08/18/22	1 / 55							
3-20	56	08/18/22	1 / 55							
3-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1380**, 3 Day - **1900**, 4 Day - **2130**, 7 Day - **2540**, 14 Day - **3010**, 28 Day - **3750**

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The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453806

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

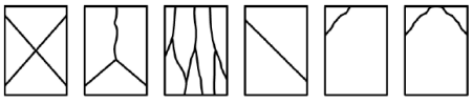
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15,16,17,18)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453809

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	4	**Technician:**	Koran, Ronald	**Batched:**	13:08 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	13:33 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	13:41 CDT
Truck / Ticket #:	713 / 5703783	**Sampled From:**	Chute	**Truck Empty:**	14:08 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC03
Plant:	16 Dayton, MN		
Sample Condition:			
On-Site Admixtures:	None		

Specifications

Strength:	4000 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3-1/2 (ASTM C143)	**Plastic Unit Weight:**	144.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	90	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
4-1	1	06/24/22	1 / 0	6.01	28.37	42,031	1,480	5	I	N
4-2	1	06/24/22	1 / 0	6.01	28.37	38,881	1,370	5	I	N
4-3	1	06/24/22	1 / 0	6.01	28.37	40,396	1,420	5	I	N
4-4	3	06/26/22	1 / 2	6.00	28.27	51,351	1,820	5	I	N
4-5	3	06/26/22	1 / 2	6.00	28.27	57,106	2,020	5	I	N
4-6	3	06/26/22	1 / 2	6.00	28.27	52,739	1,870	6	I	N
4-7	4	06/27/22	1 / 3	6.00	28.27	57,445	2,030	5	I	N
4-8	4	06/27/22	1 / 3	6.00	28.27	68,412	2,420	5	I	N
4-9	4	06/27/22	1 / 3	6.00	28.27	64,988	2,300	5	I	N
4-10	7	06/30/22	1 / 6	6.00	28.27	69,988	2,480	5	I	N
4-11	7	06/30/22	1 / 6	6.00	28.27	77,598	2,750	5	I	N
4-12	7	06/30/22	1 / 6	6.00	28.27	72,718	2,570	5	I	N
4-13	14	07/07/22	1 / 13	6.02	28.46	87,049	3,060	5	I	N
4-14	14	07/07/22	1 / 13	6.02	28.46	100,542	3,530	5	I	N
4-15	14	07/07/22	1 / 13	6.02	28.46	92,547	3,250	5	I	N
4-16	28	07/21/22	1 / 27	6.01	28.37	112,949	3,980	5	I	N
4-17	28	07/21/22	1 / 27	6.01	28.37	113,801	4,010	5	I	N
4-18	28	07/21/22	1 / 27	6.01	28.37	112,014	3,950	5	I	N
4-19	56	08/18/22	1 / 55							
4-20	56	08/18/22	1 / 55							
4-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1430**, 3 Day - **1900**, 4 Day - **2250**, 7 Day - **2600**, 14 Day - **3280**, 28 Day - **3980**

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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/27/2022
Sample: 453809

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

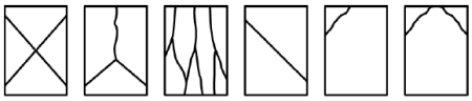
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15,16,17,18)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/27/2022
Sample: 453815

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	1	**Technician:**	Koran, Ronald	**Batched:**	09:11 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	09:36 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	09:48 CDT
Truck / Ticket #:	996 / 5703065	**Sampled From:**	Chute	**Truck Empty:**	10:11 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC01
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	2 (ASTM C143)	**Plastic Unit Weight:**	147.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	06/30/22	1 / 6	6.20	6.00	18	6,203	500	Middle	Wet	I
1-2	7	06/30/22	1 / 6	6.15	6.05	18	5,813	465	Middle	Wet	I
1-3	14	07/07/22	1 / 13	6.25	6.05	18	6,953	545	Middle	Wet	I
1-4	14	07/07/22	1 / 13	6.10	6.00	18	6,666	545	Middle	Wet	I
1-5	28	07/21/22	1 / 27	6.25	6.05	18	6,759	530	Middle	Wet	P
1-6	28	07/21/22	1 / 27	6.25	6.05	18	7,828	615	Middle	Wet	P
1-7	56	08/18/22	1 / 55								
1-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **485**, 14 Day - **545**, 28 Day - **575**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4), Ryan Kauffman (5,6)
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/27/2022
Sample: 453818

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	2	**Technician:**	Koran, Ronald	**Batched:**	10:27 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	10:52 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	11:02 CDT
Truck / Ticket #:	996 / 5703315	**Sampled From:**	Chute	**Truck Empty:**	11:27 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier: Cemstone Products Co.
Mix Design: 3A21-PCC04
Plant: 16 Dayton, MN
Sample Condition:
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	76 (ASTM C1064)	**Air Content:**	7.5 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
2-1	7	06/30/22	1 / 6	6.15	6.00	18	6,425	520	Middle	Wet	I
2-2	7	06/30/22	1 / 6	6.15	6.00	18	6,113	495	Middle	Wet	I
2-3	14	07/07/22	1 / 13	6.05	6.05	18	7,364	600	Middle	Wet	I
2-4	14	07/07/22	1 / 13	6.15	6.00	18	6,882	560	Middle	Wet	I
2-5	28	07/21/22	1 / 27	6.20	6.00	18	9,284	750	Middle	Wet	P
2-6	28	07/21/22	1 / 27	6.15	6.00	18	8,685	705	Middle	Wet	P
2-7	56	08/18/22	1 / 55								
2-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **510**, 14 Day - **580**, 28 Day - **730**

Specimen 2-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4), Ryan Kauffman (5,6)
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/27/2022
Sample: 453819

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	3	**Technician:**	Koran, Ronald	**Batched:**	11:49 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	12:14 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	12:26 CDT
Truck / Ticket #:	713 / 5703534	**Sampled From:**	Chute	**Truck Empty:**	12:49 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC05
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	142.6 (lb/ft³) (ASTM C138)
Air Temperature (F):	88	**Concrete Temp (F):**	82 (ASTM C1064)	**Air Content:**	8.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
3-1	7	06/30/22	1 / 6	6.10	6.00	18	5,400	445	Middle	Wet	I
3-2	7	06/30/22	1 / 6	6.20	6.00	18	5,639	455	Middle	Wet	I
3-3	14	07/07/22	1 / 13	6.15	6.05	18	6,512	520	Middle	Wet	I
3-4	14	07/07/22	1 / 13	6.20	6.00	18	6,576	530	Middle	Wet	I
3-5	28	07/21/22	1 / 27	6.15	6.00	18	7,737	630	Middle	Wet	P
3-6	28	07/21/22	1 / 27	6.15	6.05	18	7,713	615	Middle	Wet	P
3-7	56	08/18/22	1 / 55								
3-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **450**, 14 Day - **525**, 28 Day - **625**

Specimen 3-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4), Ryan Kauffman (5,6)
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/27/2022
Sample: 453820

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	4	**Technician:**	Koran, Ronald	**Batched:**	13:08 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	13:33 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	13:41 CDT
Truck / Ticket #:	713 / 5703783	**Sampled From:**	Chute	**Truck Empty:**	14:08 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC03
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3-1/2 (ASTM C143)	**Plastic Unit Weight:**	144.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	90	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
4-1	7	06/30/22	1 / 6	6.20	6.05	18	5,872	465	Middle	Wet	I
4-2	7	06/30/22	1 / 6	6.15	6.00	18	6,152	500	Middle	Wet	I
4-3	14	07/07/22	1 / 13	6.15	6.05	18	6,640	530	Middle	Wet	I
4-4	14	07/07/22	1 / 13	6.15	6.05	18	6,646	530	Middle	Wet	I
4-5	28	07/21/22	1 / 27	6.20	6.05	18	7,576	600	Middle	Wet	P
4-6	28	07/21/22	1 / 27	6.30	6.00	18	6,342	505	Middle	Wet	P
4-7	56	08/18/22	1 / 55								
4-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **485**, 14 Day - **530**, 28 Day - **550**

Specimen 4-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-6: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4), Ryan Kauffman (5,6)

Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

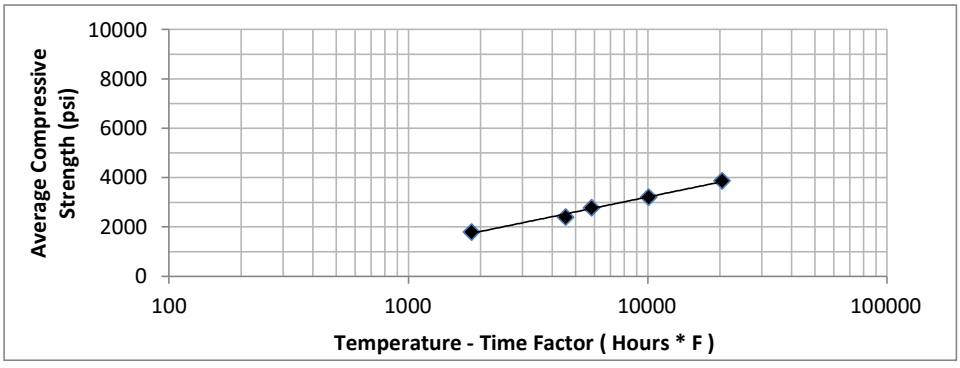
Curve Number:	0.4 w/out CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC01	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	2	Measured Air Content (%):	7.2
Ambient Temperature (F):	81	Conc. Temperature (F):	81

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1834			1834	1820	1900	1680	1800
3	4544			4544	2330	2580	2290	2400
4	5825			5825	2810	2690	2840	2780
7	10086			10086	3180	3190	3270	3210
14	20483			20483	3870	3850	3890	3870



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**868.6**	* ln(TTF) +	**-4788.7**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**24791**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

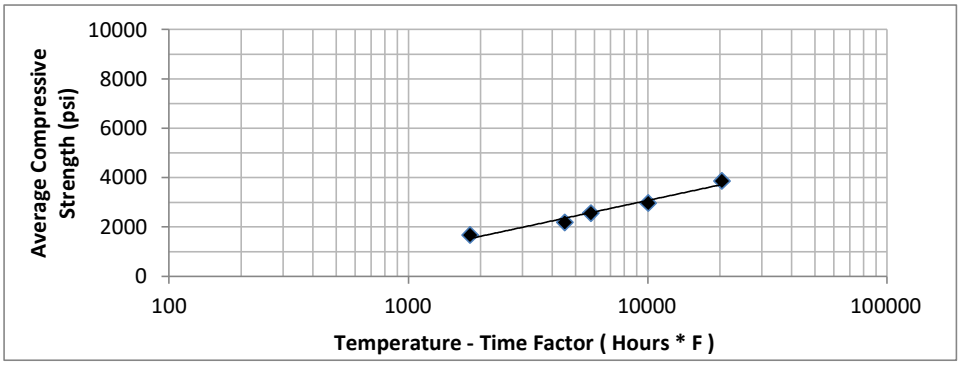
Curve Number:	0.40 w/CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC04	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3	Measured Air Content (%):	7.5
Ambient Temperature (F):	81	Conc. Temperature (F):	76

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1813			1813	1580	1680	1740	1670
3	4505			4505	2360	2010	2190	2190
4	5785			5785	2610	2660	2410	2560
7	10040			10040	3150	3050	2710	2970
14	20406			20406	4010	3910	3650	3860



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**903.4**	* ln(TTF) +	**-5249.1**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**27948**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 18, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

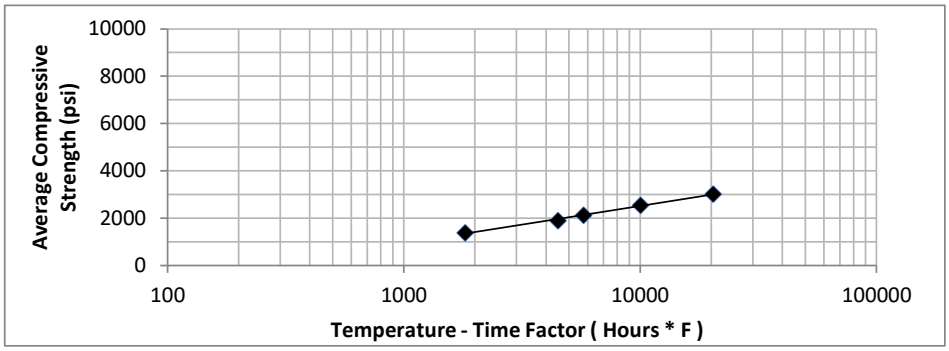
Curve Number:	0.41 w/out CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC05	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3	Measured Air Content (%):	8.8
Ambient Temperature (F):	81	Conc. Temperature (F):	82

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1816			1816	1410	1390	1330	1380
3	4486			4486	2010	1760	1930	1900
4	5768			5768	2210	2080	2110	2130
7	10028			10028	2350	2620	2640	2540
14	20388			20388	3140	2800	3080	3010



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**685.1** * ln(TTF) +		**-3796.8**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**87599**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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Minneapolis, MN 55438

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Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 18, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

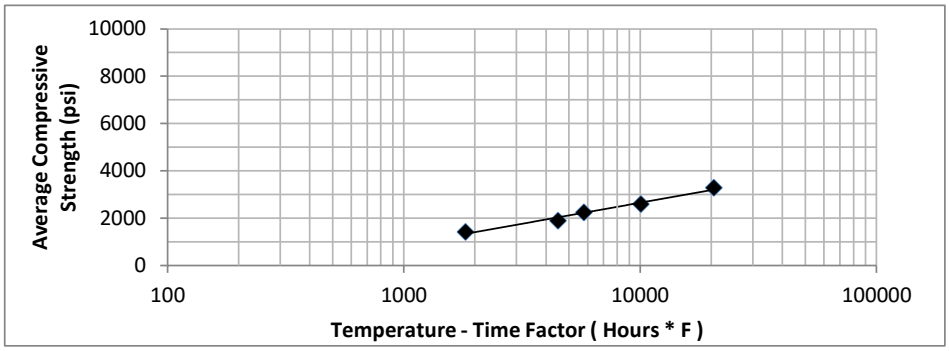
Curve Number:	0.41 w/ CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC03	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3.5	Measured Air Content (%):	7.8
Ambient Temperature (F):	81	Conc. Temperature (F):	81

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1823			1823	1480	1370	1420	1420
3	4495			4495	1820	2020	1870	1900
4	5785			5785	2030	2420	2300	2250
7	10074			10074	2480	2750	2570	2600
14	20482			20482	3060	3530	3250	3280



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**772.8**	* ln(TTF) +	**-4468.7**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**57438**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Contin./Davenport	CONDAIL	IL(10)	3.10
Fly Ash	EM/Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	MBS	MAIR90	AEA	0.1-10
Admx#2	MBS	AMPOL1020	A	0-12
Admx#3	MBS	SMMAT358	S	0-6
Admx#4	MBS	BMSTDELVO	B	0-5
Admx#5	MBS	SMSREZ60	S	0-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71002	SAND		2.66	0.008
FA#2					
CA#1	71002	#67	C	2.70	0.014
CA#2	71002	3/4"+	C	2.65	0.016
CA#3					

SP Number	8680-191
Contract ID	220071
Requested By	Kevin Heindel
Company	Cemstone Products Company
Phone	651-686-4233
Email	kheindel@cemstone.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Cemstone - Dayton (#16)
Plant/Unit #	RM229
Contractor	
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													45		42	13					
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-PCC01	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-PCC03	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3
3A21-PCC04	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-PCC05	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: MnROAD Carbon Cure Mix Designs - Mixes PCC03 and PCC04 will have 6 oz/yd of CarbonCure. For trial batching purposes, final mix design approval, mix name and JMF assignment will occur prior to construction.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

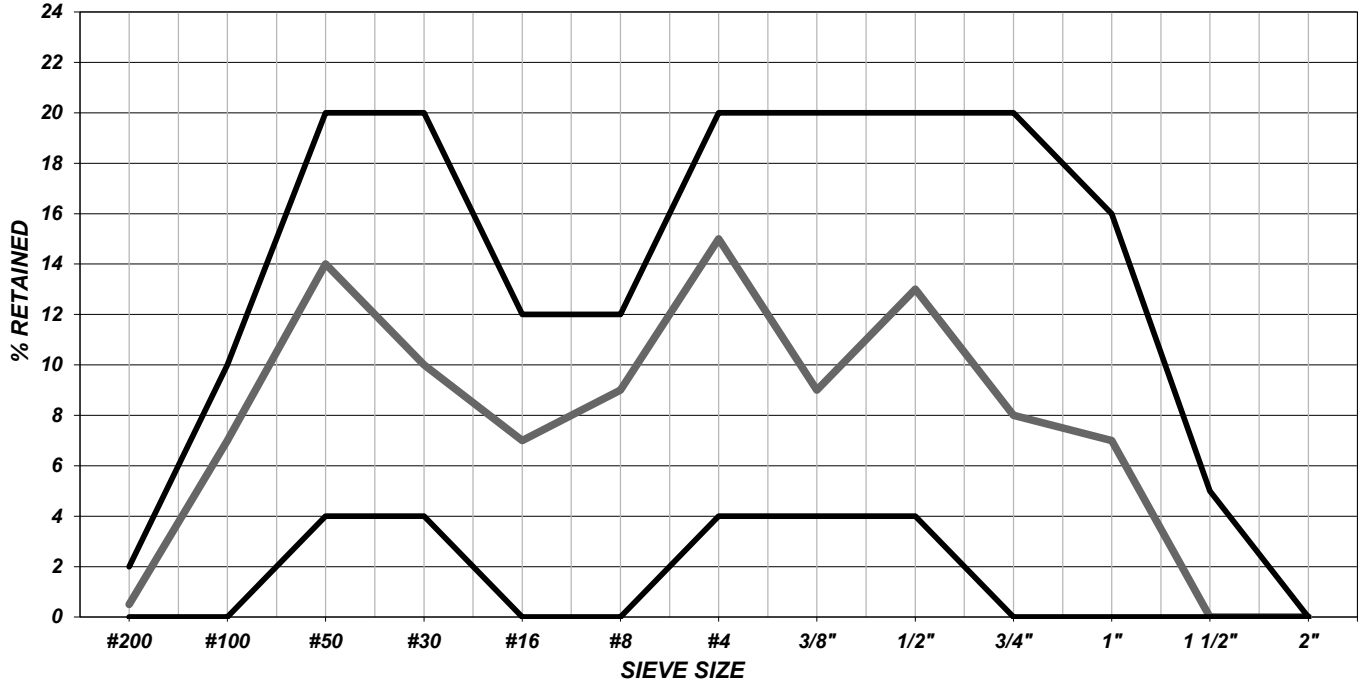
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		100%	LIMITS			
2"	100.0		100.0	100.0		100	± 5	95	100	0
1 1/2"	100.0		100.0	100.0		100	± 5	95	100	0
1"	100.0		100.0	49.0		93	± 5	88	98	7
3/4"	100.0		95.0	3.0		85	± 5	80	90	8
1/2"	100.0		63.0	1.0		72	± 5	67	77	13
3/8"	100.0		43.0	0.0		63	± 5	58	68	9
#4	99.0		8.0	0.0		48	± 5	43	53	15
#8	87.0		0.0	0.0		39	± 4	35	43	9
#16	71.0		0.0	0.0		32	± 4	28	36	7
#30	48.0		0.0	0.0		22	± 4	18	26	10
#50	17.0		0.0	0.0		8	± 3	5	11	14
#100	3.0		0.0	0.0		1	± 2	0	3	7
#200	1.0		0.0	0.0		0.5	≤ 1.6	0.0	1.6	1

Mix #
3A21-PCC01
3A21-PCC03
3A21-PCC04
3A21-PCC05

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
CarbonCure

Prepared for

CarbonCure Technologies

Project B2205765
July 15, 2022

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 15, 2022 Project B2205156

Ms. Shannon Seipel
CarbonCure Technologies
42 Payzant Ave.
Dartmouth, NS B3B 1Z6
Canada

Re: MnROAD Trial Batching
CarbonCure Technologies

Dear Ms. Seipel:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. CarbonCure, will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Testing Summary and Results

Plastic testing was performed at Cemstone Ready-mix batch plant along with casting of specimens for strength testing. The specimens were then transported to our Bloomington laboratory for testing. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Additional Note

Additional ages for compressive strength were conducted and presented in the attachments. The 60-minute test data was not conducted due to timing of the truck batches and adjustments to the load.

Table 2. Data Summary

Proportions				
Materials / Mix Designs (Oven Dry Weights)	**3A21-PCC01**	**3A21-PCC03**	**3A21-PCC04**	**3A21-PCC05**
Continental Davenport, (lbs/yd3)	399	387	399	387
Coal Creek, (lbs/yd^3)	171	166	171	166
Sand - Pit #71002, (lbs/yd^3)	1367	1374	1367	1374
# 67- Pit #71002, (lbs/yd^3)	1295	1301	1295	1301
3/4 + - Pit # 71002, (lbs/yd^3)	393	395	393	395
Water, (lbs/yd^3)	228	228	225	228
MBS Miro Air90, (oz/cwt)	0.1-10	0.1-11	0.1-12	0.1-13
MBS Polyhee 1020 , (oz/cwt)	1-12	1-13	1-14	1-15
MBS, Master Matrix 358, (oz/cwt)	0-6	0-6	0-6	0-6
MBS, Master Set Delvo, (oz/cwt)	0-3	0-3	0-3	0-3
MBS, MasterSure Z 60 (oz/cwt)	0-12	0-12	0-12	0-12
CarbonCure	0	6.0	6.0	0

Plastic Testing								
Test	**Initial**	**30 Mins**	**Initial**	**30 Mins**	**Initial**	**30 Mins**	**Initial**	**30 Mins**
Slump (inches)	**2**	**1.75**	**3.5**	**1.75**	**3**	**2.5**	**3**	**1.5**
Air content (%)	**7.2**	**6.81**	**7.8**	**6.8**	**8.8**	**7.5**	**8.6**	**6.9**
SAM	**0.16**	**0.17**	**0.14**	**0.26**	**0.26**	**N/A**	**0.13**	**0.19**
Box test visual rating	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**0**
Box test slump (inches)	**5/16**	**1/8**	**1/16**	**1/16**	**1/8**	**1/4**	**1/4**	**1/16**
Unit weight	**145.3**		**144.4**		**147.3**		**142.6**	
Time of set - Initial (min)	**218**		**258**		**268**		**233**	
Time of set - Final (min)	**296**		**362**		**355**		**330**	

Strength								
Age (Days)	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**	**Flexural (psi)**	**Compressive (psi)**
7	485	3210	485	2600	510	2970	450	2540
14	545	3870	530	3280	580	3850	525	3010
28	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

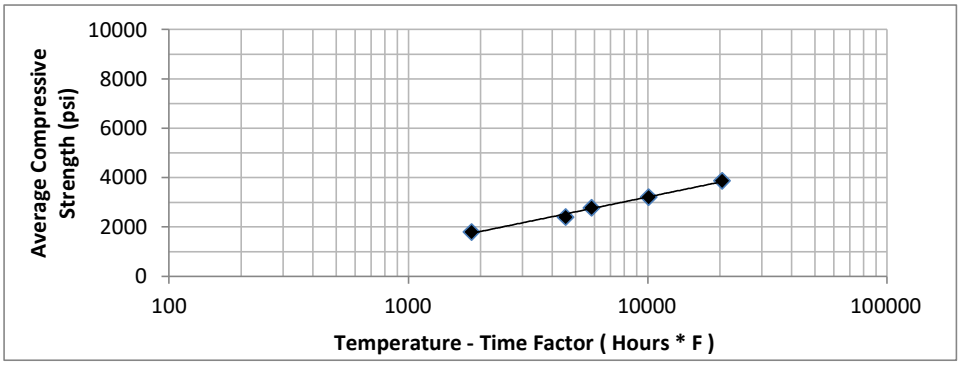
Curve Number:	0.4 w/out CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC01	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	2	Measured Air Content (%):	7.2
Ambient Temperature (F):	81	Conc. Temperature (F):	81

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1834			1834	1820	1900	1680	1800
3	4544			4544	2330	2580	2290	2400
4	5825			5825	2810	2690	2840	2780
7	10086			10086	3180	3190	3270	3210
14	20483			20483	3870	3850	3890	3870



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**868.6** * ln(TTF) +		**-4788.7**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**24791**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

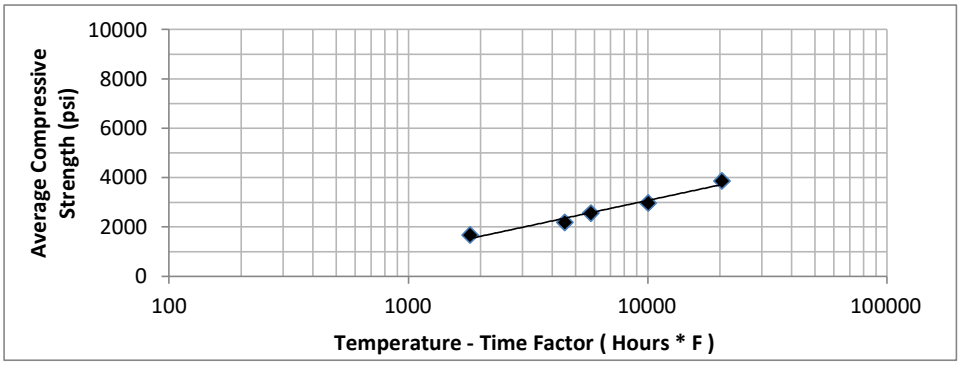
Curve Number:	0.40 w/CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC04	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3	Measured Air Content (%):	7.5
Ambient Temperature (F):	81	Conc. Temperature (F):	76

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1813			1813	1580	1680	1740	1670
3	4505			4505	2360	2010	2190	2190
4	5785			5785	2610	2660	2410	2560
7	10040			10040	3150	3050	2710	2970
14	20406			20406	4010	3910	3650	3860



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**903.4**	* ln(TTF) +	**-5249.1**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**27948**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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Minneapolis, MN 55438

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Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 18, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

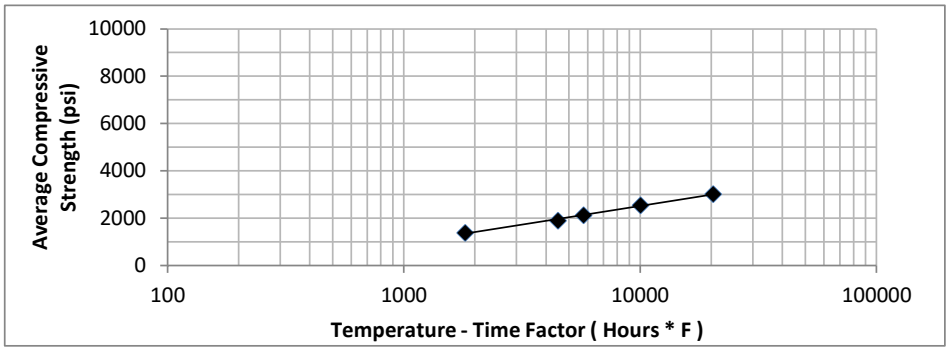
Curve Number:	0.41 w/out CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC05	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3	Measured Air Content (%):	8.8
Ambient Temperature (F):	81	Conc. Temperature (F):	82

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1816			1816	1410	1390	1330	1380
3	4486			4486	2010	1760	1930	1900
4	5768			5768	2210	2080	2110	2130
7	10028			10028	2350	2620	2640	2540
14	20388			20388	3140	2800	3080	3010



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**685.1** * ln(TTF) +		**-3796.8**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**87599**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 18, 2022

Project Number: B2205156

Client:
CarbonCure Technologies, Inc.
42 Payzant Ave.
Dartmouth, NS B3B 1Z6

Project Description:
CarbonCure MnROAD Trial Batching

Curve Information

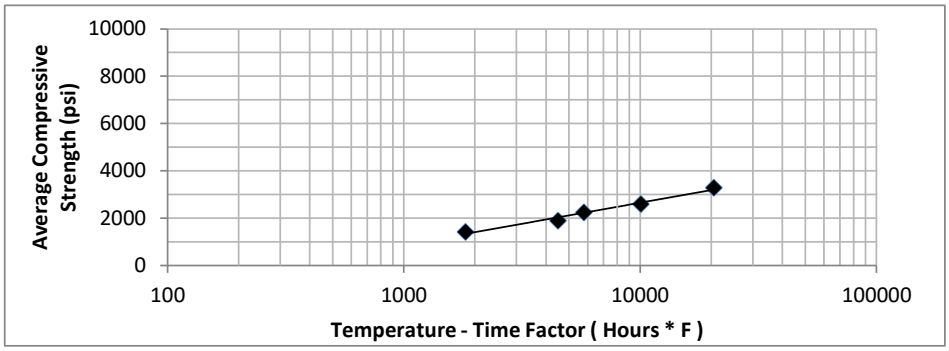
Curve Number:	0.41 w/ CarbonCure	Cast By:	Ron Koran
Cylinder Cast Date:	June 23, 2022		

Specifications and Properties

Mixture Identification:	3A21-PCC03	Specified Strength (psi):	4000
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	3.5	Measured Air Content (%):	7.8
Ambient Temperature (F):	81	Conc. Temperature (F):	81

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1823			1823	1480	1370	1420	1420
3	4495			4495	1820	2020	1870	1900
4	5785			5785	2030	2420	2300	2250
7	10074			10074	2480	2750	2570	2600
14	20482			20482	3060	3530	3250	3280



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**772.8**	* ln(TTF) +	**-4468.7**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4000**	Required Maturity (Hours *F):		**57438**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

BRAUN INTERTEC
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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453800

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	1	**Technician:**	Koran, Ronald	**Batched:**	09:11 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	09:36 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	09:48 CDT
Truck / Ticket #:	996 / 5703065	**Sampled From:**	Chute	**Truck Empty:**	10:11 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC01
Plant:	16 Dayton, MN		
Sample Condition:			
On-Site Admixtures:	None		

Specifications

Strength:	4000 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	2 (ASTM C143)	**Plastic Unit Weight:**	147.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	06/24/22	1 / 0	6.01	28.37	51,728	1,820	5	I	N
1-2	1	06/24/22	1 / 0	6.01	28.37	53,870	1,900	5	I	N
1-3	1	06/24/22	1 / 0	6.01	28.37	47,779	1,680	5	I	N
1-4	3	06/26/22	1 / 2	6.00	28.27	65,757	2,330	5	I	N
1-5	3	06/26/22	1 / 2	6.00	28.27	72,839	2,580	5	I	N
1-6	3	06/26/22	1 / 2	6.00	28.27	64,618	2,290	4	I	N
1-7	4	06/27/22	1 / 3	6.00	28.27	79,363	2,810	5	I	N
1-8	4	06/27/22	1 / 3	6.00	28.27	76,128	2,690	5	I	N
1-9	4	06/27/22	1 / 3	6.00	28.27	80,148	2,840	5	I	N
1-10	7	06/30/22	1 / 6	6.00	28.27	89,968	3,180	5	I	N
1-11	7	06/30/22	1 / 6	6.00	28.27	90,058	3,190	5	I	N
1-12	7	06/30/22	1 / 6	6.00	28.27	92,336	3,270	5	I	N
1-13	14	07/07/22	1 / 13	6.02	28.46	110,159	3,870	5	I	N
1-14	14	07/07/22	1 / 13	6.02	28.46	109,676	3,850	5	I	N
1-15	14	07/07/22	1 / 13	6.02	28.46	110,671	3,890	5	I	N
1-16	28	07/21/22	1 / 27							
1-17	28	07/21/22	1 / 27							
1-18	28	07/21/22	1 / 27							
1-19	56	08/18/22	1 / 55							
1-20	56	08/18/22	1 / 55							
1-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1800**, 3 Day - **2400**, 4 Day - **2780**, 7 Day - **3210**, 14 Day - **3870**

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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453800

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

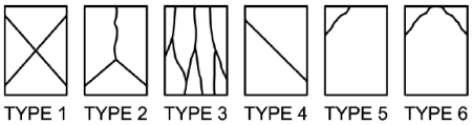
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453805

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	2	**Technician:**	Koran, Ronald	**Batched:**	10:27 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	10:52 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	11:07 CDT
Truck / Ticket #:	996 / 5703315	**Sampled From:**	Chute	**Truck Empty:**	11:27 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier: Cemstone Products Co.
Plant: 16 Dayton, MN
Mix Design: 3A21-PCC04
Sample Condition:
On-Site Admixtures: None

Specifications

Strength: 4000 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	76 (ASTM C1064)	**Air Content:**	7.5 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
2-1	1	06/24/22	1 / 0	6.01	28.37	44,727	1,580	5	I	N
2-2	1	06/24/22	1 / 0	6.01	28.37	47,627	1,680	5	I	N
2-3	1	06/24/22	1 / 0	6.01	28.37	49,339	1,740	5	I	N
2-4	3	06/26/22	1 / 2	6.00	28.27	66,677	2,360	6	I	N
2-5	3	06/26/22	1 / 2	6.00	28.27	56,676	2,010	6	I	N
2-6	3	06/26/22	1 / 2	6.00	28.27	61,797	2,190	5	I	N
2-7	4	06/27/22	1 / 3	6.00	28.27	73,699	2,610	5	I	N
2-8	4	06/27/22	1 / 3	6.00	28.27	75,223	2,660	5	I	N
2-9	4	06/27/22	1 / 3	6.00	28.27	68,072	2,410	5	I	N
2-10	7	06/30/22	1 / 6	6.00	28.27	89,078	3,150	5	I	N
2-11	7	06/30/22	1 / 6	6.00	28.27	86,121	3,050	5	I	N
2-12	7	06/30/22	1 / 6	6.00	28.27	76,475	2,710	5	I	N
2-13	14	07/07/22	1 / 13	6.02	28.46	114,111	4,010	5	I	N
2-14	14	07/07/22	1 / 13	6.02	28.46	111,154	3,910	5	I	N
2-15	14	07/07/22	1 / 13	6.02	28.46	103,740	3,650	5	I	N
2-16	28	07/21/22	1 / 27							
2-17	28	07/21/22	1 / 27							
2-18	28	07/21/22	1 / 27							
2-19	56	08/18/22	1 / 55							
2-20	56	08/18/22	1 / 55							
2-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1670**, 3 Day - **2180**, 4 Day - **2560**, 7 Day - **2970**, 14 Day - **3850**

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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453805

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

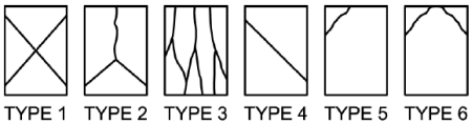
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



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Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453806

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	3	**Technician:**	Koran, Ronald	**Batched:**	11:49 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	12:14 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	12:26 CDT
Truck / Ticket #:	713 / 5703534	**Sampled From:**	Chute	**Truck Empty:**	12:49 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC05
Plant:	16 Dayton, MN		
Sample Condition:			
On-Site Admixtures:	None		

Specifications

Strength:	4000 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	142.6 (lb/ft³) (ASTM C138)
Air Temperature (F):	88	**Concrete Temp (F):**	82 (ASTM C1064)	**Air Content:**	8.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
3-1	1	06/24/22	1 / 0	6.01	28.37	40,116	1,410	5	I	N
3-2	1	06/24/22	1 / 0	6.01	28.37	39,283	1,390	5	I	N
3-3	1	06/24/22	1 / 0	6.01	28.37	37,791	1,330	5	I	N
3-4	3	06/26/22	1 / 2	6.00	28.27	56,842	2,010	5	I	N
3-5	3	06/26/22	1 / 2	6.00	28.27	49,604	1,760	5	I	N
3-6	3	06/26/22	1 / 2	6.00	28.27	54,451	1,930	5	I	N
3-7	4	06/27/22	1 / 3	6.00	28.27	62,567	2,210	2	I	N
3-8	4	06/27/22	1 / 3	6.00	28.27	58,652	2,080	5	I	N
3-9	4	06/27/22	1 / 3	6.00	28.27	59,587	2,110	5	I	N
3-10	7	06/30/22	1 / 6	6.00	28.27	66,292	2,350	5	I	N
3-11	7	06/30/22	1 / 6	6.00	28.27	74,174	2,620	5	I	N
3-12	7	06/30/22	1 / 6	6.00	28.27	74,551	2,640	5	I	N
3-13	14	07/07/22	1 / 13	6.02	28.46	89,304	3,140	5	I	N
3-14	14	07/07/22	1 / 13	6.02	28.46	79,695	2,800	5	I	N
3-15	14	07/07/22	1 / 13	6.02	28.46	87,532	3,080	5	I	N
3-16	28	07/21/22	1 / 27							
3-17	28	07/21/22	1 / 27							
3-18	28	07/21/22	1 / 27							
3-19	56	08/18/22	1 / 55							
3-20	56	08/18/22	1 / 55							
3-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1380**, 3 Day - **1900**, 4 Day - **2130**, 7 Day - **2540**, 14 Day - **3010**

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453806

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

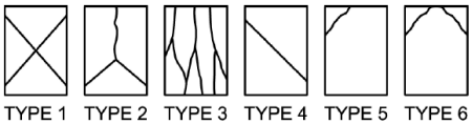
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453809

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	4	**Technician:**	Koran, Ronald	**Batched:**	13:08 CDT
Specimen Size:	6" X 12"	**Cast By:**	Koran, Ronald	**Sampled:**	13:33 CDT
Specimens In Set:	21	**Date Cast:**	06/23/22	**Cast:**	13:41 CDT
Truck / Ticket #:	713 / 5703783	**Sampled From:**	Chute	**Truck Empty:**	14:08 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone Plant - Dayton, MN
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC03
Plant:	16 Dayton, MN		
Sample Condition:			
On-Site Admixtures:	None		

Specifications

Strength:	4000 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3-1/2 (ASTM C143)	**Plastic Unit Weight:**	144.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	90	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
4-1	1	06/24/22	1 / 0	6.01	28.37	42,031	1,480	5	I	N
4-2	1	06/24/22	1 / 0	6.01	28.37	38,881	1,370	5	I	N
4-3	1	06/24/22	1 / 0	6.01	28.37	40,396	1,420	5	I	N
4-4	3	06/26/22	1 / 2	6.00	28.27	51,351	1,820	5	I	N
4-5	3	06/26/22	1 / 2	6.00	28.27	57,106	2,020	5	I	N
4-6	3	06/26/22	1 / 2	6.00	28.27	52,739	1,870	6	I	N
4-7	4	06/27/22	1 / 3	6.00	28.27	57,445	2,030	5	I	N
4-8	4	06/27/22	1 / 3	6.00	28.27	68,412	2,420	5	I	N
4-9	4	06/27/22	1 / 3	6.00	28.27	64,988	2,300	5	I	N
4-10	7	06/30/22	1 / 6	6.00	28.27	69,988	2,480	5	I	N
4-11	7	06/30/22	1 / 6	6.00	28.27	77,598	2,750	5	I	N
4-12	7	06/30/22	1 / 6	6.00	28.27	72,718	2,570	5	I	N
4-13	14	07/07/22	1 / 13	6.02	28.46	87,049	3,060	5	I	N
4-14	14	07/07/22	1 / 13	6.02	28.46	100,542	3,530	5	I	N
4-15	14	07/07/22	1 / 13	6.02	28.46	92,547	3,250	5	I	N
4-16	28	07/21/22	1 / 27							
4-17	28	07/21/22	1 / 27							
4-18	28	07/21/22	1 / 27							
4-19	56	08/18/22	1 / 55							
4-20	56	08/18/22	1 / 55							
4-21	56	08/18/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1430**, 3 Day - **1900**, 4 Day - **2250**, 7 Day - **2600**, 14 Day - **3280**

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/15/2022
Sample: 453809

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

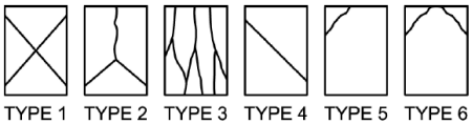
Client:

CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:

B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

	Capping Methods
I: The result is for informational purposes. **Tested By:** Ryan Kauffman (1,2,3), Reid Swanson (4,5,6), Mitch Kalahar (7,8,9,10,11,12), Yee Lee (13,14,15)	**N:** ASTM C1231, Unbonded Caps
Checked In : 06/24/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/15/2022
Sample: 453815

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	1	**Technician:**	Koran, Ronald	**Batched:**	09:11 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	09:36 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	09:48 CDT
Truck / Ticket #:	996 / 5703065	**Sampled From:**	Chute	**Truck Empty:**	10:11 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC01
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	2 (ASTM C143)	**Plastic Unit Weight:**	147.8 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	06/30/22	1 / 6	6.20	6.00	18	6,203	500	Middle	Wet	I
1-2	7	06/30/22	1 / 6	6.15	6.05	18	5,813	465	Middle	Wet	I
1-3	14	07/07/22	1 / 13	6.25	6.05	18	6,953	545	Middle	Wet	I
1-4	14	07/07/22	1 / 13	6.10	6.00	18	6,666	545	Middle	Wet	I
1-5	28	07/21/22	1 / 27								
1-6	28	07/21/22	1 / 27								
1-7	56	08/18/22	1 / 55								
1-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **485**, 14 Day - **545**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4)

Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/15/2022
Sample: 453818

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	2	**Technician:**	Koran, Ronald	**Batched:**	10:27 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	10:52 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	11:02 CDT
Truck / Ticket #:	996 / 5703315	**Sampled From:**	Chute	**Truck Empty:**	11:27 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC04
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	147.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	81	**Concrete Temp (F):**	76 (ASTM C1064)	**Air Content:**	7.5 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
2-1	7	06/30/22	1 / 6	6.15	6.00	18	6,425	520	Middle	Wet	I
2-2	7	06/30/22	1 / 6	6.15	6.00	18	6,113	495	Middle	Wet	I
2-3	14	07/07/22	1 / 13	6.05	6.05	18	7,364	600	Middle	Wet	I
2-4	14	07/07/22	1 / 13	6.15	6.00	18	6,882	560	Middle	Wet	I
2-5	28	07/21/22	1 / 27								
2-6	28	07/21/22	1 / 27								
2-7	56	08/18/22	1 / 55								
2-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **510**, 14 Day - **580**

Specimen 2-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 2-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4)

Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/15/2022
Sample: 453819

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	3	**Technician:**	Koran, Ronald	**Batched:**	11:49 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	12:14 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	12:26 CDT
Truck / Ticket #:	713 / 5703534	**Sampled From:**	Chute	**Truck Empty:**	12:49 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC05
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3 (ASTM C143)	**Plastic Unit Weight:**	142.6 (lb/ft³) (ASTM C138)
Air Temperature (F):	88	**Concrete Temp (F):**	82 (ASTM C1064)	**Air Content:**	8.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
3-1	7	06/30/22	1 / 6	6.10	6.00	18	5,400	445	Middle	Wet	I
3-2	7	06/30/22	1 / 6	6.20	6.00	18	5,639	455	Middle	Wet	I
3-3	14	07/07/22	1 / 13	6.15	6.05	18	6,512	520	Middle	Wet	I
3-4	14	07/07/22	1 / 13	6.20	6.00	18	6,576	530	Middle	Wet	I
3-5	28	07/21/22	1 / 27								
3-6	28	07/21/22	1 / 27								
3-7	56	08/18/22	1 / 55								
3-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **450**, 14 Day - **525**

Specimen 3-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 3-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4)

Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/15/2022
Sample: 453820

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
CarbonCure Technologies Inc
60 Trider Crescent
Dartmouth, NS B3B 1R6

Project:
B2205156
MnROAD
MnROADSP 8680-174 (TH 94=392)9011 77th Street...
Monticello, MN 55362

Sample Details

Set #:	4	**Technician:**	Koran, Ronald	**Batched:**	13:08 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Koran, Ronald	**Sampled:**	13:33 CDT
Specimens In Set:	8	**Date Cast:**	06/23/22	**Cast:**	13:41 CDT
Truck / Ticket #:	713 / 5703783	**Sampled From:**	Chute	**Truck Empty:**	14:08 CDT
Contractor:		**Placement Method:**	Chute	**Placement Time:**	60 (min)

Location

Placement Location: Lab Cast
Location Details: Cemstone - Dayton
Sample Location / Notes: Cemstone - Dayton

Batch Log

Supplier:	Cemstone Products Co.	**Mix Design:**	3A21-PCC03
Plant:	16 Dayton, MN		
Sample Condition:			

Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture:	500 (psi)
Air:	5 - 8 (%)
Slump:	1/2 - 3 (in)

Field Measurements

Weather:	Clear	**Slump (in):**	3-1/2 (ASTM C143)	**Plastic Unit Weight:**	144.3 (lb/ft³) (ASTM C138)
Air Temperature (F):	90	**Concrete Temp (F):**	81 (ASTM C1064)	**Air Content:**	7.8 (ASTM C231)
				Load Volume:	3.00 (yd³)

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
4-1	7	06/30/22	1 / 6	6.20	6.05	18	5,872	465	Middle	Wet	I
4-2	7	06/30/22	1 / 6	6.15	6.00	18	6,152	500	Middle	Wet	I
4-3	14	07/07/22	1 / 13	6.15	6.05	18	6,640	530	Middle	Wet	I
4-4	14	07/07/22	1 / 13	6.15	6.05	18	6,646	530	Middle	Wet	I
4-5	28	07/21/22	1 / 27								
4-6	28	07/21/22	1 / 27								
4-7	56	08/18/22	1 / 55								
4-8	56	08/18/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **485**, 14 Day - **530**

Specimen 4-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 4-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4)

Checked In : 06/24/2022 (1,2,3,4,5,6,7,8)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Contin./Davenport	CONDAIL	IL(10)	3.10
Fly Ash	EM/Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	MBS	MAIR90	AEA	0.1-10
Admx#2	MBS	AMPOL1020	A	0-12
Admx#3	MBS	SMMAT358	S	0-6
Admx#4	MBS	BMSTDELVO	B	0-5
Admx#5	MBS	SMSREZ60	S	0-12
Fiber				
Color				

Use for:

Paving Projects 3,500 CY or greater

Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71002	SAND		2.66	0.008
FA#2					
CA#1	71002	#67	C	2.70	0.014
CA#2	71002	3/4"+	C	2.65	0.016
CA#3					

SP Number	8680-191
Contract ID	220071
Requested By	Kevin Heindel
Company	Cemstone Products Company
Phone	651-686-4233
Email	kheindel@cemstone.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Cemstone - Dayton (#16)
Plant/Unit #	RM229
Contractor	
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													45		42	13					
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21-PCC01	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-PCC03	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3
3A21-PCC04	7.0	228	399	171			30				570	0.40	1367		1295	393		27.0	142.7	25.2	1/2 - 3
3A21-PCC05	7.0	228	387	166			30				553	0.41	1374		1301	395		27.0	142.6	24.9	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments: MnROAD Carbon Cure Mix Designs - Mixes PCC03 and PCC04 will have 6 oz/yd of CarbonCure. For trial batching purposes, final mix design approval, mix name and JMF assignment will occur prior to construction.

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

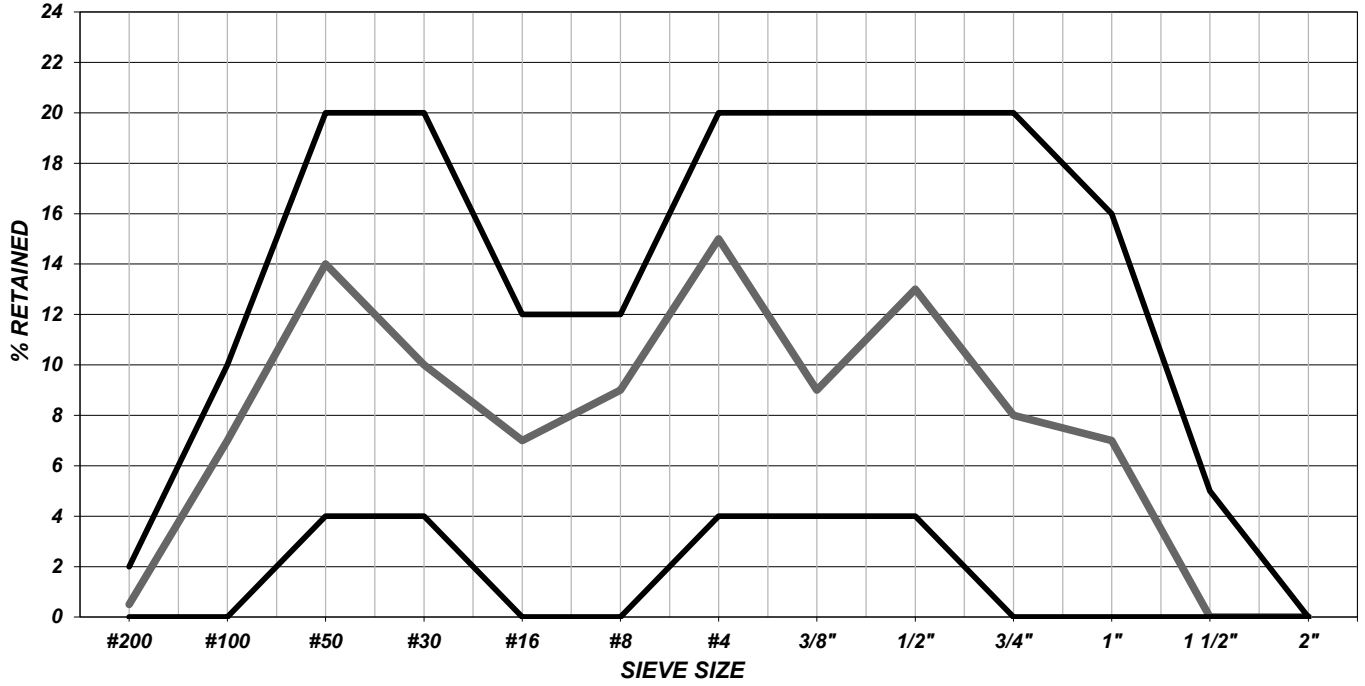
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	SAND		#67	3/4"+						
Prop. %	45		42	13		100%	LIMITS			
2"	100.0		100.0	100.0		100	± 5	95	100	0
1 1/2"	100.0		100.0	100.0		100	± 5	95	100	0
1"	100.0		100.0	49.0		93	± 5	88	98	7
3/4"	100.0		95.0	3.0		85	± 5	80	90	8
1/2"	100.0		63.0	1.0		72	± 5	67	77	13
3/8"	100.0		43.0	0.0		63	± 5	58	68	9
#4	99.0		8.0	0.0		48	± 5	43	53	15
#8	87.0		0.0	0.0		39	± 4	35	43	9
#16	71.0		0.0	0.0		32	± 4	28	36	7
#30	48.0		0.0	0.0		22	± 4	18	26	10
#50	17.0		0.0	0.0		8	± 3	5	11	14
#100	3.0		0.0	0.0		1	± 2	0	3	7
#200	1.0		0.0	0.0		0.5	≤ 1.6	0.0	1.6	1

Mix #
3A21-PCC01
3A21-PCC03
3A21-PCC04
3A21-PCC05

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
26
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
32
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
3M Company, 3M Natural Pozzolan

Prepared for

3M Company

Project B2205346
July 15, 2022

Braun Intertec Corporation

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 15, 2022 Project B2205346

Mr. John Edwards
3M Company
3M Center, 209-01-W-14
St. Paul, MN 55144

Re: MnROAD Trial Batching
3M Company, 3M Natural Pozzolan

Dear Mr. Edwards:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. 3M Natural Pozzolan manufactured by 3M Company, will be used in the pavement of one of the test cells as a replacement of 15 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions		
Materials	**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)
Prairie State Fly Ash	85	(lbs/yd^3)
3M Natural Pozzolan	85	(lbs/yd^3)
Sand - Pit #71041	1209	(lbs/yd^3)
3/4 in + - Pit #19129	472	(lbs/yd^3)
#67 - Pit #71041	1205	(lbs/yd^3)
CIA – Pit #71041	252	(lbs/yd^3)
Water	228	(lbs/yd^3)
Sika Air 260	1.6-2.0*	(oz/cwt)
Sika Visocrete 1000	0.1-0.6*	(oz/cwt)
Sikatard 440	2	(oz/cwt)
Stabilizer 4R	1	(oz/cwt)

Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	1-1/2	1-1/4	1
Air content (%)	5.1	5.0	4.8
SAM	0.02	0.10	0.30
Unit weight (lbs/yd^3)	148.4		
Box test visual Rating	1	1.5	2.5
Box testing slump (inches)	1/16	1/16	0

Time of Set		
	Initial (min)	**Final (min)**
Time of Set	336	438

Strength		
Age	**Flexural (psi)**	**Compressive (psi)**
7	400	3520
14	445	TBD
28	515	TBD
56	N/A	TBD

Note * Air dosage required 3 to 4 time the control mixture. HRWA required 10 to 60 percent of control.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions	Dry Weights	
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)
Prairie State Fly Ash	85	(lbs/yd^3)
3M Natural Pozzolan	85	(lbs/yd^3)
Sand - Pit #71041	1209	(lbs/yd^3)
3/4 in + - Pit #19129	472	(lbs/yd^3)
#67 - Pit #71041	1205	(lbs/yd^3)
CIA – Pit #71041	252	(lbs/yd^3)
Water	228	(lbs/yd^3)
Sika Air 260	1.6-2.0	(oz/cwt)
Sika Visocrete 1000	0.1-0.6	(oz/cwt)
Sikatard 440	2	(oz/cwt)
Stabilizer 4R	1	(oz/cwt)

The plastic test results are summarized in table 4 below. Multiple batches were required to conduct all the testing.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump each side (in)			
1	72	141.7	7.8	2-3/4						
2-Initial	72	148.4	5.1	1-1/2	0.02	1	1/8	1/8	1/8	1/8
2- 30 Minutes		146.2	5.0	1-1/4	0.10	1.5	1/8	1/8	1/16	1/16
2- 60 Minutes		147.1	4.8	1	0.30	2.5	0	0	1/16	1/16

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age (days)	Average Modulus of Rupture (psi)
1	7	400
1	14	445
1	28	515
1	56	N/A

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	1960
2	3	3240
2	4	3220
2	7	3520
3	14	TBD
2	28	TBD
3	56	TBD

The result time of set are presented in table 7 below.

Table 7. Time of Set

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	336	438

Additional Note

Admixture dosing notes: Water reducer, Hydration stabilizer and retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between 3 to 4 times that of control mix. High range water reducer requirement is 10 to 60 percent of the control mixture.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/14/2022
Sample: 456365

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
3M Company
Building 275-6W-22
Saint Paul, MN 55144

Project:
B2205346
MnROAD 3M Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	12:38 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	13:50 CDT
Specimens In Set:	21	**Date Cast:**	07/05/22	**Cast:**	14:00 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 15% replacement with flyash and 15% replacement with 3M Material
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 15 % replacement of Flyash and 15% replacement of 3M Material
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-1/2 (ASTM C143)	**Plastic Unit Weight:**	148.4 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	73 (ASTM C1064)	**Air Content:**	5.1 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

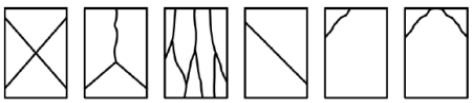
Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	07/06/22	1 / 0	6.00	28.27	56,359	1,990	5	I	N
1-2	1	07/06/22	1 / 0	6.00	28.27	53,697	1,900	5	I	N
1-3	1	07/06/22	1 / 0	6.00	28.27	55,959	1,980	5	I	N
1-4	3	07/08/22	1 / 2	5.99	28.18	94,493	3,350	5	I	N
1-5	3	07/08/22	1 / 2	5.99	28.18	84,809	3,010	5	I	N
1-6	3	07/08/22	1 / 2	5.99	28.18	94,719	3,360	5	I	N
1-7	4	07/09/22	1 / 3	6.02	28.46	86,815	3,050	5	I	N
1-8	4	07/09/22	1 / 3	6.02	28.46	99,486	3,500	5	I	N
1-9	4	07/09/22	1 / 3	6.02	28.46	88,942	3,130	5	I	N
1-10	7	07/12/22	1 / 6	6.02	28.46	86,257	3,030	5	I	N
1-11	7	07/12/22	1 / 6	6.02	28.46	108,567	3,820	5	I	N
1-12	7	07/12/22	1 / 6	6.02	28.46	105,407	3,700	5	I	N

Test Age Average Strengths (psi): 1 Day - **1960**, 3 Day - **3240**, 4 Day - **3220**, 7 Day - **3520**

I: The result is for informational purposes.
Tested By: Mitch Kalahar (1,2,3,4,5,6,7,8,9,10,11,12)
Checked In : 07/06/2022 (1,2,3,4,5,6,7,8,9,10,11,12)

Capping Methods

N: ASTM C1231, Unbonded Caps



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Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/15/2022
Sample: 449693

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
3M Company
Building 275-6W-22
Saint Paul, MN 55144

Project:
B2205346
MnROAD 3M Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	12:10 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	12:30 CDT
Specimens In Set:	8	**Date Cast:**	06/09/22	**Cast:**	12:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 3M Natural Pozzolan 15% and Flyash 15% replacement
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 3M Natural Pozzolan 15% and Flyash 15% replacement
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Consistency:**	Slump	**Plastic Unit Weight:**	141.7 (lb/ft³) (ASTM C138)
Air Temperature (F):	73	**Concrete Temp (F):**	71 (ASTM C1064)	**Air Content:**	7.8 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	06/16/22	1 / 6	6.00	6.00	18	5,076	425	Middle	Wet	I
1-2	7	06/16/22	1 / 6	6.10	6.05	18	4,622	375	Middle	Wet	I
1-3	14	06/23/22	1 / 13	6.05	6.00	18	5,542	460	Middle	Wet	I
1-4	14	06/23/22	1 / 13	6.05	6.00	18	5,213	430	Middle	Wet	I
1-5	28	07/07/22	1 / 27	6.00	6.00	18	6,069	505	Middle	Wet	P
1-6	28	07/07/22	1 / 27	6.10	6.00	18	6,380	525	Middle	Wet	P
1-7	21	06/30/22	1 / 20	6.10	6.05	18	6,149	495	Middle	Wet	I
1-8	21	06/30/22	1 / 20	6.00	6.00	18	6,240	520	Middle	Wet	I

Test Age Average Strengths (psi): 7 Day - **400**, 14 Day - **445**, 28 Day - **515**, 21 Day - **510**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-5: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-6: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-7: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-8: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.
P: The result meets or exceeds the flexural strength of the project's specifications.

Tested By: Mitch Kalahar (1,2,3,4), Yee Lee (5,6), John Pomranke (7,8)
Checked In : 06/10/2022 (1,2,3,4,5,6,7,8)

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 14, 2022

Project Number: B2205346

Client:
3M Company
3M Center, 209-01-W-14
St. Paul, MN 55144

Project Description:
MnROAD 3M Batching
3M Natural Pozzolan

Curve Information

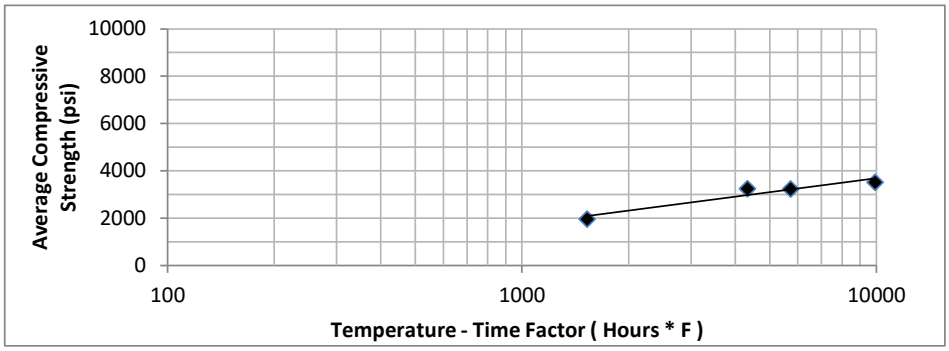
Curve Number:	3M - 15%	Cast By:	John Pomranke
Cylinder Cast Date:	July 5, 2022		

Specifications and Properties

Mixture Identification:	3M - 15%; Fly Ash - 15%	Specified Strength (psi):	4500
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	1.5	Measured Air Content (%):	5.1
Ambient Temperature (F):	70	Conc. Temperature (F):	73

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1526			1526	1990	1900	1980	1960
3	4320			4320	3350	3010	3360	3240
4	5719			5719	3050	3500	3130	3230
7	9911			9911	3030	3820	3700	3520



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**853.8** * ln(TTF) +		**-4174.7**
Datum Temperature)°F):	**14**			
Target Field Strength (psi):	**4500**	Required Maturity (Hours *F):		**25851**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Minnesota Department of Transportation CONC-203 (4/19/22)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	3M Natural Pozzolan			2.70
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	**% Air**	**Water**	**Cement**	**Fly Ash**	**Slag**	**Other CM**	**% Fly Ash**	**% Slag**	**% Other CM**	**% Ternary**	**Total CM**	**W/C Ratio**	**FA#1**	**FA#2**	**CA#1**	**CA#2**	**CA#3**	**Volume**	**Unit Wt.**	**% Paste Volume**	**Slump Range, in**
3A21- 3M	7.0	228	400	85		85	15		15	30	570	0.40	1209		472	1205	252	27.0	145.7	23.1	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

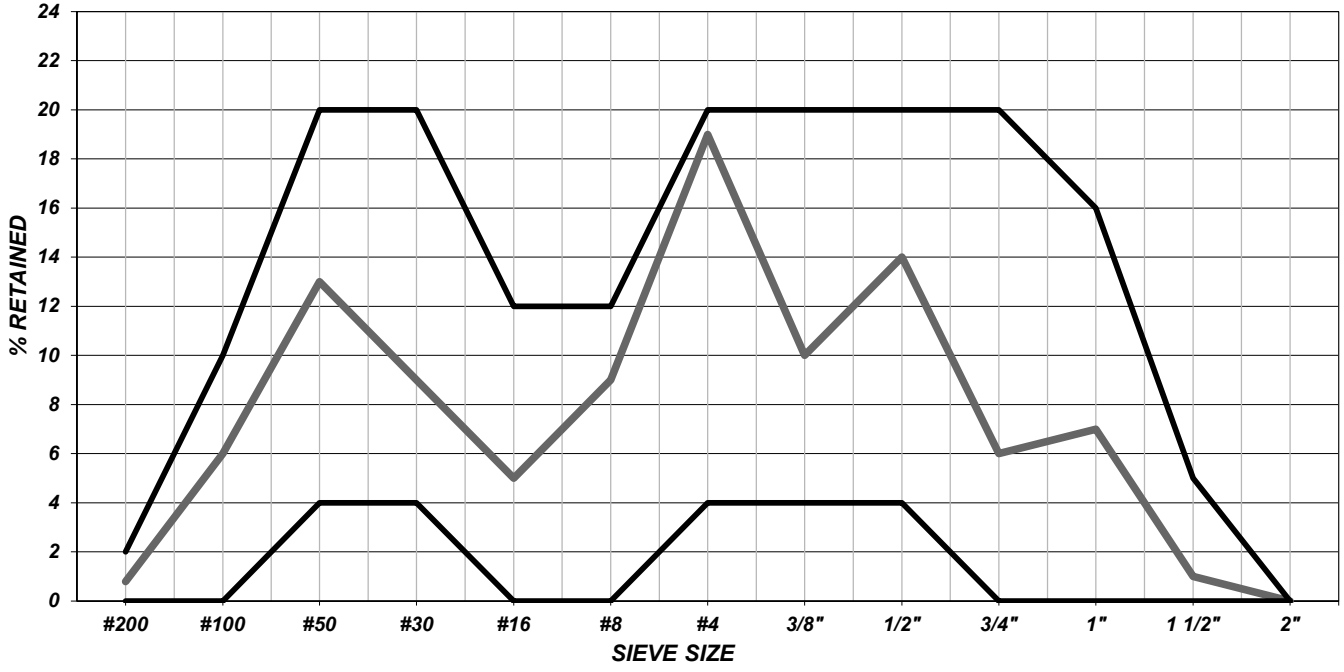
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	38	8	100%				
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	10
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- 3M

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
Carbon Limit

Prepared for

Carbon Limit

Project B2206453
July 27, 2022

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 27, 2022 Project B2206453

Mr. Angel Pedroza
Carbon Limit
901 NW 35th St.
Boca Raton, FL 33431

Re: MnROAD Trial Batching
Carbon Limit

Dear Mr. Pedroza:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. An Enhanced Pozzolan, manufactured by Carbon Limit, will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions			
Materials		**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL		400	(lbs/yd^3)
Carbon Limit		170	(lbs/yd^3)
Sand - Pit #71041		1186	(lbs/yd^3)
3/4 in + - Pit #19129		451	(lbs/yd^3)
#67 - Pit #71041		1122	(lbs/yd^3)
CIA – Pit #71041		241	(lbs/yd^3)
Water		228	(lbs/yd^3)
Sika Air 260		1.5-2.0	(oz/cwt)
Sika Visocrete 1000		3.0-6.5	(oz/cwt)
Sikatard 440		2	(oz/cwt)
Stabilizer 4R		1	(oz/cwt)
Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	2 ½	¼	¼
Air content (%)	7.9	6.1	4.9
SAM	0.20	0.30	NA
Unit weight (lbs/yd^3)	143.1		
Box test visual Rating	1	3	4
Box testing slump (inches)	0	0	Sheared
Time of Set			
	Initial (min)	**Final (min)**	
Time of Set	497	598	
Strength			
Age	**Flexural (psi)**	**Compressive (psi)**	
7	475		
14	605		
28			
56			

Note * Air dosage required 4 to 6 time the control mixture. HRWA required 2 to 3 time the dosage for control.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions	Dry Weights	
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)
Hess Natural Pozzolan	170	(lbs/yd^3)
Sand - Pit #71041	1154	(lbs/yd^3)
3/4 in + - Pit #19129	451	(lbs/yd^3)
#67 - Pit #71041	1150	(lbs/yd^3)
CIA – Pit #71041	240	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	1.5-2.0	(oz/cwt)
Sika Visocrete 1000	3.0-6.5	(oz/cwt)
Sikatard 440	2	(oz/cwt)
Stabilizer 4R	1	(oz/cwt)

The plastic test results are summarized in table 4 below. Multiple batches were required to conduct all the testing.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump each side (in)			
1	71	143.9	7.1	1-1/2						
2-Initial	70	143.1	7.9	2-1/2	0.20	1	0	0	0	0
2- 30 Minutes			6.1	1/4	0.30	3	0	0	0	0
2- 60 Minutes			4.9	1/4	NA	4	Shear	Shear	Shear	Shear

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age (days)	Average Modulus of Rupture (psi)
1	7	475
1	14	605
1	28	
1	56	

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	2410
2	3	4020
2	4	4790
2	7	
3	14	
2	28	
3	56	

The result time of set are presented in table 7 below.

Table 7. Time of Set

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	267	365

Additional Note

Admixture dosing notes: Air entraining admixture dosage requirement varied between 1 to 1.5 times the dose of control mix. High range water reducer dosage required 1 to 2.5 times the control dosage. The high range water reducer in the second batch was likely elevated due to the length of time required to achieve slump and air content desirable.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/26/2022
Sample: 461675

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Carbon Limit Co.
901 NW 35th Street
Boca Raton, FL 33431

Project:
B2206453
MnRoad Carbon Limit Cement Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	09:09 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	10:45 CDT
Specimens In Set:	21	**Date Cast:**	07/21/22	**Cast:**	11:00 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement with Carbon Limit Material
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% replacement with Carbon Limit Material
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/2 (ASTM C143)	**Plastic Unit Weight:**	143.1 (lb/ft³) (ASTM C138)
Air Temperature (F):	70	**Concrete Temp (F):**	70 (ASTM C1064)	**Air Content:**	7.9 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	07/22/22	1 / 0	5.99	28.18	65,998	2,250	2	I	N
1-2	1	07/22/22	1 / 0	5.99	28.18	71,301	2,430	2	I	N
1-3	1	07/22/22	1 / 0	5.99	28.18	74,589	2,540	2	I	N
1-4	3	07/24/22	1 / 2	6.01	28.37	119,549	4,050	4	I	N
1-5	3	07/24/22	1 / 2	6.01	28.37	113,462	3,850	4	I	N
1-6	3	07/24/22	1 / 2	6.01	28.37	122,634	4,150	5	I	N
1-7	4	07/25/22	1 / 3	6.01	28.37	129,829	4,580	3	I	N
1-8	4	07/25/22	1 / 3	6.01	28.37	138,525	4,880	3	I	N
1-9	4	07/25/22	1 / 3	6.00	28.27	138,623	4,900	5	I	N
1-10	7	07/28/22	1 / 6							
1-11	7	07/28/22	1 / 6							
1-12	7	07/28/22	1 / 6							
1-13	14	08/04/22	1 / 13							
1-14	14	08/04/22	1 / 13							
1-15	14	08/04/22	1 / 13							
1-16	28	08/18/22	1 / 27							
1-17	28	08/18/22	1 / 27							
1-18	28	08/18/22	1 / 27							
1-19	56	09/15/22	1 / 55							
1-20	56	09/15/22	1 / 55							
1-21	56	09/15/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **2410**, 3 Day - **4020**, 4 Day - **4790**

I: The result is for informational purposes.
Tested By: Mitch Kalahar (1,2,3,9), Reid Swanson (4,5,6), Yee Lee (7,8)
Checked In : 07/22/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)

Capping Methods

N: ASTM C1231, Unbonded Caps

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/26/2022
Sample: 461675

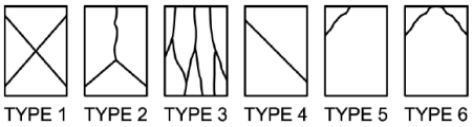
11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:

Carbon Limit Co.
901 NW 35th Street
Boca Raton, FL 33431

Project:

B2206453
MnRoad Carbon Limit Cement Batching
Bloomington Lab
Bloomington, MN 55438



BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/26/2022
Sample: 457877

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Carbon Limit Co.
901 NW 35th Street
Boca Raton, FL 33431

Project:
B2206453
MnRoad Carbon Limit Cement Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	08:00 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	08:30 CDT
Specimens In Set:	8	**Date Cast:**	07/11/22	**Cast:**	08:45 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement with Carbon Limit Material
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% replacement with Carbon Limit Material
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-1/2 (ASTM C143)	**Plastic Unit Weight:**	143.9 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	72 (ASTM C1064)	**Air Content:**	7.1 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	07/18/22	1 / 6	6.15	6.05	18	5,807	465	Middle	Wet	I
1-2	7	07/18/22	1 / 6	6.20	6.00	18	5,982	480	Middle	Wet	I
1-3	14	07/25/22	1 / 13	6.15	6.00	18	7,823	635	Middle	Wet	I
1-4	14	07/25/22	1 / 13	6.15	6.00	18	7,114	580	Middle	Wet	I
1-5	28	08/08/22	1 / 27								
1-6	28	08/08/22	1 / 27								
1-7	56	09/05/22	1 / 55								
1-8	56	09/05/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **475**, 14 Day - **605**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: Mitch Kalahar (1,2), Yee Lee (3,4)

Checked In : 07/12/2022 (1,2,3,4,5,6,7,8)

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Carbon Limit			2.06
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													40		15	37	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21- CL	7.0	228	400			170			30		570	0.40	1186		451	1122	241	27.0	140.7	26.1	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

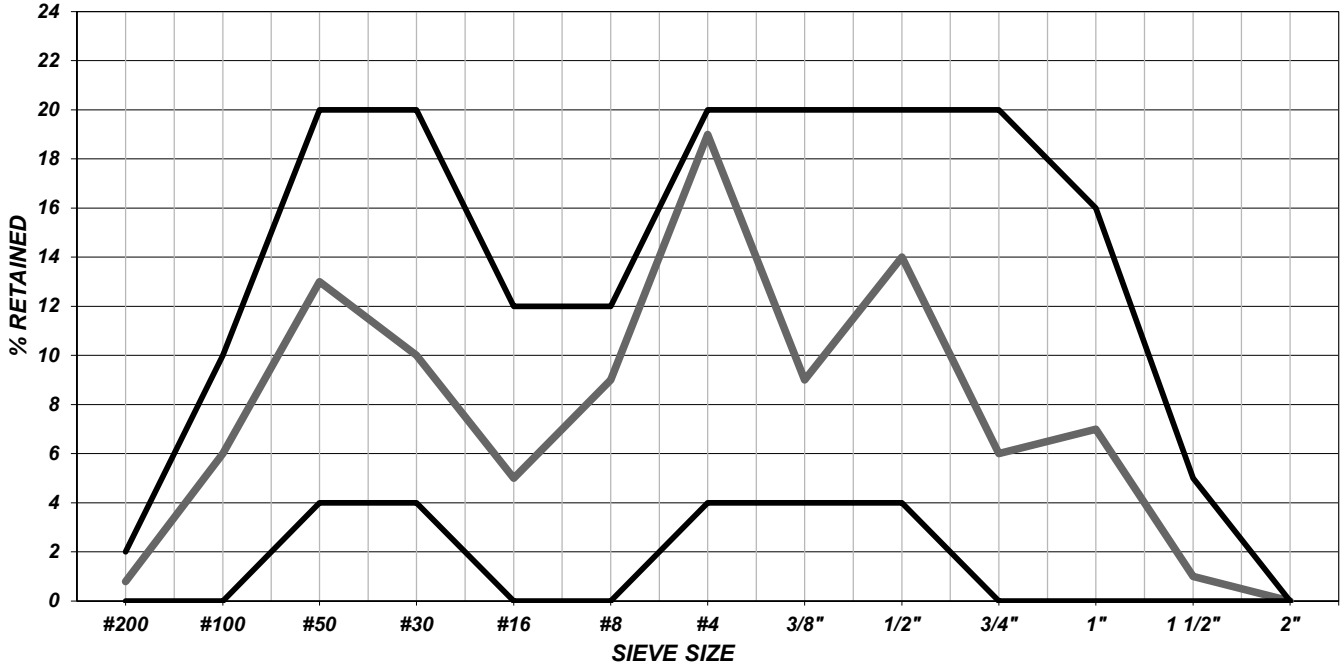
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	40		15	37	8	100%				
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	63	± 5	58	68	9
#4	99.0		0.0	4.1	32.9	44	± 5	39	49	19
#8	88.2			0.0	0.8	35	± 4	31	39	9
#16	74.4				0.1	30	± 4	26	34	5
#30	50.7					20	± 4	16	24	10
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- CL

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
24
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
30
Between 24-34%, generally enhances workability of the mix.

Trial Batching Report

MnROAD Final Trial Batching
Hess Pumice Products, Natural Pozzolan

Prepared for

Hess Pumice Products

Project B2205765
July 15, 2022

Braun Intertec Corporation

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

July 15, 2022 Project B2205765

Mr. Brian Jeppsen
Hess Pumice Products
100 Hess Dr.
Malad, ID 83252

Re: MnROAD Trial Batching
Hess Pumice Products, Natural Pozzolan

Dear Mr. Jeppsen:

Braun Intertec Corporation is pleased to provide this letter to report the results of the concrete trial batching for 2022 construction of research cells at MnROAD.

Background

The National Road Research Alliance is placing new concrete test sections at MnROAD for the 2022 construction season using non-conventional materials. Natural Pozzolan, manufactured by Hess Pumice Products, will be used in the pavement of one of the test cells as a replacement of 30 percent of the cement in the concrete mixture.

A trail batch was required with test results outlined in table 1 below:

Table 1. Requirements of Final Trail Batch

Standard Test	Requirement	Procedure
Flexural strength	500 psi at 28 days	ASTM C78
Compressive strength	Report only	ASTM C39
Air content	5-8%	ASTM C231
SAM	Report only	AASHTO T118
Slump	Report only	ASTM C143
Unit weight	Report only	ASTM C138
Box test	Report only	AASHTO TP137
Set time	Initial set- 90 minute minimum	ASTM C403
Estimating concrete strength by maturity	Report only	ASTM C1074

Executive Summary

Testing was performed at our laboratory in Bloomington, Minnesota. The summary table below contains the primary data required for construction. The testing required multiple laboratory batches to complete this testing and additional test results and details of our product evaluation are presented in the body of the report. The batch weight presented below are in oven dry weights.

Table 2. Summary of Results

Proportions			
Materials		**Oven Dry Weights**	
Cement – Holcim St. Genevieve IL		400	(lbs/yd^3)
Hess Natural Pozzolan		170	(lbs/yd^3)
Sand - Pit #71041		1154	(lbs/yd^3)
3/4 in + - Pit #19129		451	(lbs/yd^3)
#67 - Pit #71041		1150	(lbs/yd^3)
CIA – Pit #71041		240	(lbs/yd^3)
Water		239	(lbs/yd^3)
Sika Air 260		2.0-3.0*	(oz/cwt)
Sika Visocrete 1000		2.0-3.0*	(oz/cwt)
Sikatard 440		2	(oz/cwt)
Stabilizer 4R		1	(oz/cwt)
Plastic Testing			
Test	**Initial**	**30 min**	**60 min**
Slump (inches)	2-1/4	1-3/4	1-1/2
Air content (%)	6.7	6.5	7.2
SAM	0.12	0.12	0.30
Unit weight (lbs/yd^3)	144.9		
Box test visual Rating	1	1	1
Box testing slump (inches)	1/8	1/8	1/16
Time of Set			
	Initial (min)	**Final (min)**	
Time of Set	497	598	
Strength			
Age	**Flexural (psi)**	**Compressive (psi)**	
7	445	2920	
14	485	TBD	
28	TBD	TBD	
56	TBD	TBD	

Note * Air dosage required 4 to 6 time the control mixture. HRWA required 2 to 3 time the dosage for control.

Trial Batch and Test Results

The proportions of the mixture are in Table 3 below.

Table 3. Trial Batch Mixture Proportion

Proportions	Dry Weights	
Cement – Holcim St. Genevieve IL	400	(lbs/yd^3)
Hess Natural Pozzolan	170	(lbs/yd^3)
Sand - Pit #71041	1154	(lbs/yd^3)
3/4 in + - Pit #19129	451	(lbs/yd^3)
#67 - Pit #71041	1150	(lbs/yd^3)
CIA – Pit #71041	240	(lbs/yd^3)
Water	239	(lbs/yd^3)
Sika Air 260	2.0-3.0	(oz/cwt)
Sika Visocrete 1000	2.0-3.0	(oz/cwt)
Sikatard 440	2	(oz/cwt)
Stabilizer 4R	1	(oz/cwt)

The plastic test results are summarized in table 4 below. Multiple batches were required to conduct all the testing.

Table 4. Plastic Tests

Batch	Concrete Temperature (F)	Unit Weight (lbs/ft3)	Air Content C231 (%)	Slump (in)	SAM	Box Test Visual Average Rank	Box Test Edge Slump each side (in)			
1	71	145.3	6.2	1-3/4						
2-Initial	71	144.9	6.7	2-1/4	0.12	1	1/16	1/16	1/8	1/8
2- 30 Minutes			6.5	1-3/4	0.12	1	1/8	1/8	1/8	1/8
2- 60 Minutes			7.2	1-1/2	0.30	1	1/8	1/16	1/16	1/16

The flexural strengths are summarized in Table 5 below.

Table 5. Flexural Strength

Batch Number	Test Age (days)	Average Modulus of Rupture (psi)
1	7	445
1	14	485
1	28	TBD
1	56	TBD

The compressive strengths are summarized in Table 6 below.

Table 6. Compressive Strength

Batch Number	Test Age, Days	Average Compressive Strength (psi)
2	1	1580
2	3	2230
2	4	2550
2	7	2920
3	14	TBD
2	28	TBD
3	56	TBD

The result time of set are presented in table 7 below.

Table 7. Time of Set

Batch Number	Initial Set (minutes)	Final Set (minutes)
1	374	458

Additional Note

Admixture dosing notes: Water reducer, Hydration stabilizer and retarder dosage comparable to control mix. Air entraining admixture dosage requirement varied between 4 to 6 time the dose of control mix. High range water reducer dosage required 2 to 3 times the control dosage.

General

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions, please contact John Pomranke at 218.929.1099 or JPomranke@braunintertec.com.

Sincerely,

BRAUN INTERTEC CORPORATION

John Pomranke
Concrete Laboratory Operations Manager

Alfred J. Gardiner, PE
Director Concrete Consulting, Principal Engineer

Attachments:
Laboratory Test Reports

Laboratory Test Reports

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/14/2022
Sample: 456064

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Hess Pumice Products, Inc.
100 Hess Drive
Malad, ID 83252

Project:
B2205765
Hess Pumice MnROAD Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	09:58 CDT
Specimen Size:	6" X 12"	**Cast By:**	Pomranke, John	**Sampled:**	11:10 CDT
Specimens In Set:	21	**Date Cast:**	06/30/22	**Cast:**	11:15 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement of Hess Pumice Standard Pozzolan
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% replacement of Hess Pumice Standard Pozzolan
On-Site Admixtures: None

Specifications

Strength: 4500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	2-1/4 (ASTM C143)	**Plastic Unit Weight:**	144.9 (lb/ft³) (ASTM C138)
Air Temperature (F):	69	**Concrete Temp (F):**	70 (ASTM C1064)	**Air Content:**	7.2 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Cylinder Diameter (in)	Cylinder Area (in²)	Max Load (lbs)	Strength (psi)	Fracture Type	Break Remark	Capping Method
1-1	1	07/01/22	1 / 0	6.00	28.27	44,235	1,570	2	I	N
1-2	1	07/01/22	1 / 0	6.00	28.27	47,256	1,670	2	I	N
1-3	1	07/01/22	1 / 0	6.00	28.27	42,811	1,510	2	I	N
1-4	3	07/03/22	1 / 2	6.01	28.37	65,651	2,310	2	I	N
1-5	3	07/03/22	1 / 2	6.00	28.27	61,232	2,170	2	I	N
1-6	3	07/03/22	1 / 2	6.00	28.27	65,003	2,300	5	I	N
1-7	4	07/04/22	1 / 3	6.00	28.27	71,851	2,540	2	I	N
1-8	4	07/04/22	1 / 3	6.00	28.27	77,810	2,750	2	I	N
1-9	4	07/04/22	1 / 3	6.00	28.27	66,783	2,360	2	I	N
1-10	7	07/07/22	1 / 6	6.02	28.46	77,968	2,740	5	I	N
1-11	7	07/07/22	1 / 6	6.02	28.46	85,314	3,000	5	I	N
1-12	7	07/07/22	1 / 6	6.02	28.46	85,752	3,010	5	I	N
1-13	14	07/14/22	1 / 13	6.01	28.37	90,262	3,180	5	I	N
1-14	14	07/14/22	1 / 13	6.01	28.37	82,139	2,900	5	I	N
1-15	14	07/14/22	1 / 13	6.01	28.37	82,946	2,920	5	I	N
1-16	28	07/28/22	1 / 27							
1-17	28	07/28/22	1 / 27							
1-18	28	07/28/22	1 / 27							
1-19	56	08/25/22	1 / 55							
1-20	56	08/25/22	1 / 55							
1-21	56	08/25/22	1 / 55							

Test Age Average Strengths (psi): 1 Day - **1580**, 3 Day - **2260**, 4 Day - **2550**, 7 Day - **2920**, 14 Day - **3000**

BRAUN INTERTEC
The Science You Build On.

Compressive Strength of Concrete

Test Method: ASTM C39

Report Date: 07/14/2022
Sample: 456064

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

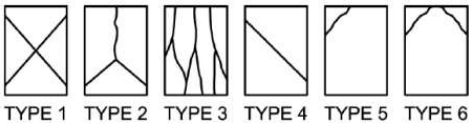
Client:

Hess Pumice Products, Inc.
100 Hess Drive
Malad, ID 83252

Project:

B2205765
Hess Pumice MnROAD Batching
Bloomington Lab
Bloomington, MN 55438

	Capping Methods
I: The result is for informational purposes. **Tested By:** Mitch Kalahar (1,2,3,13,14,15), John Pomranke (4,5,6,7,8,9), Yee Lee (10,11,12)	**N:** ASTM C1231, Unbonded Caps
Checked In : 07/01/2022 (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)	



John Pomranke
07/14/2022

BRAUN INTERTEC
The Science You Build On.

Concrete Modulus of Rupture

Test Method: ASTM C78

Report Date: 07/14/2022
Sample: 454922

11001 Hampshire Avenue S
Minneapolis, MN 55438
Phone: 952-995-2000

Client:
Hess Pumice Products, Inc.
100 Hess Drive
Malad, ID 83252

Project:
B2205765
Hess Pumice MnROAD Batching
Bloomington Lab
Bloomington, MN 55438

Sample Details

Set #:	1	**Technician:**	Pomranke, John	**Batched:**	13:48 CDT
Specimen Size:	6" X 6" X 20"	**Cast By:**	Pomranke, John	**Sampled:**	14:15 CDT
Specimens In Set:	8	**Date Cast:**	06/27/22	**Cast:**	14:30 CDT
Truck / Ticket #:		**Sampled From:**	Mixer	**Truck Empty:**	
Contractor:		**Placement Method:**		**Placement Time:**	

Location

Placement Location: Lab Cast
Location Details: 30% replacement with Hess Standard Pozzolan
Sample Location / Notes: Bloomington Lab

Batch Log

Supplier: Bloomington Lab
Mix Design: 30% Replacement Hess Standard Pozzolan
Beam Fabrication Method: Vibrated (ASTM C31)
On-Site Admixtures: None

Specifications

Mod. of Rupture: 500 (psi)
Air: 5 - 8 (%)
Slump: 1/2 - 3 (in)

Field Measurements

Weather:		**Slump (in):**	1-3/4 (ASTM C143)	**Plastic Unit Weight:**	148.5 (lb/ft³) (ASTM C138)
Air Temperature (F):	72	**Concrete Temp (F):**	71 (ASTM C1064)	**Air Content:**	6.2 (ASTM C231)
				Load Volume:	

Lab Test Results

Testing Lab: Bloomington, 11001 Hampshire Ave S, Bloomington, MN

Specimen Number	Test Age Days	Test Date	Field / Lab Cure Days	Average Width (in)	Average Depth (in)	Span (in)	Load (lbs)	Modulus of Rupture (psi)	Fracture Location	Wet / Dry	Break Remark
1-1	7	07/04/22	1 / 6	6.10	6.05	18	5,669	455	Middle	Wet	I
1-2	7	07/04/22	1 / 6	6.10	6.00	18	5,301	435	Middle	Wet	I
1-3	14	07/11/22	1 / 13	6.05	6.00	18	5,578	460	Middle	Wet	I
1-4	14	07/11/22	1 / 13	6.20	6.00	18	6,264	505	Middle	Wet	I
1-5	28	07/25/22	1 / 27								
1-6	28	07/25/22	1 / 27								
1-7	56	08/22/22	1 / 55								
1-8	56	08/22/22	1 / 55								

Test Age Average Strengths (psi): 7 Day - **445**, 14 Day - **485**

Specimen 1-1: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-2: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-3: **Testing Method -** Leather Shims, **Forming Method -** Molded
Specimen 1-4: **Testing Method -** Leather Shims, **Forming Method -** Molded

Break Remarks

I: The result is for informational purposes.

Tested By: John Pomranke (1,2), Yee Lee (3,4)

Checked In : 06/28/2022 (1,2,3,4,5,6,7,8)

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Standard Practice for Estimating Concrete Strength By Maturity Method
ASTM C 1074

Date: July 15, 2022

Project Number: B2205765

Client:
Hess Pumice Products
100 Hess Dr.
Malad, ID 83252

Project Description:
MnROAD Batching
Hess Natural Pozzolan

Curve Information

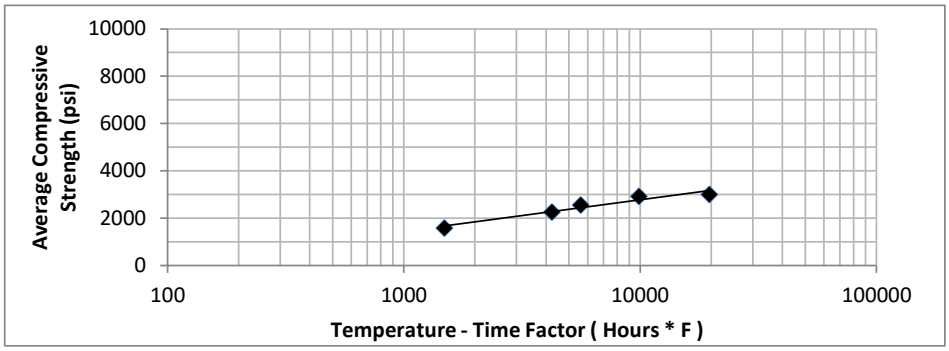
Curve Number:	Hess - 30%	Cast By:	John Pomranke
Cylinder Cast Date:	June 30, 2022		

Specifications and Properties

Mixture Identification:	Hess - 30% Standard	Specified Strength (psi):	4500
Target Slump: (in)	1/2 to 3	Target Air Content: (%)	5 to 8
Measured Slump (in.):	2.25	Measured Air Content (%):	6.2
Ambient Temperature (F):	70	Conc. Temperature (F):	70

Laboratory Data

	Maturity Readings (Hours * F)				Compressive Strength (psi)			
Age	Meter 1	Meter 2	Meter 3	Average	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	1485			1485	1570	1670	1510	1580
3	4224			4224	2310	2170	2300	2260
4	5593			5593	2540	2750	2360	2550
7	9870			9870	2740	3000	3010	2920
14	19612			19612	3180	2900	2920	3000



		Slope (B)		Intercept (A)
Maturity Function:	Compressive Strength =	**580.3** * ln(TTF) +		**-2570.6**
Datum Temperature (F):	**14**			
Target Field Strength (psi):	**4500**	Required Maturity (Hours *F):		**195710**

Notes: Due to normal variations in compressive strength of concrete cylinders, a safety factor may be required on the field target strength or the required maturity.

Reviewed By:

John Pomranke
Concrete Labortory Operations Manager

Project Specific Paving Mix Design (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/Class	SP.G / Dosage
Cement	Holcim St. Genevieve	STGBLIL	IL(10)	3.10
Fly Ash				
Slag				
Other CM	Hess Pumice Standard			2.30
Admx#1	Sika Air 260	SIAIR260	AEA	As needed
Admx#2	Sika Visocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	2-8
Admx#4	Stabilizer 4R	SSISA4R	S	1-7
Admx#5				
Fiber				
Color				

Use for:
Paving Projects 3,500 CY or greater
Job Specific Concrete using a JMF

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	Sand		2.63	0.009
FA#2					
CA#1	19129	3/4+	C	2.67	0.012
CA#2	71041	#67	C	2.69	0.013
CA#3	71041	CIA	C	2.67	0.015

SP Number	8680-191
Contract ID	
Requested By	Dustin Forester
Company	Aggregate Industries
Phone	612-961-2218
Email	dustin.forester@holcim.com
Agency Contact	Ben Worel
Agency Phone	651-358-1328
Agency Email	ben.worel@state.mn.us
Plant Name	Rogers
Plant/Unit #	841/RM051
Contractor	PCI Roads
JMF Number	

All weights are in lb/cy. Aggregates are considered to be Oven Dry.

													% Aggregate Proportion by Volume								
													39		15	38	8				
Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Unit Wt.	% Paste Volume	Slump Range, in
3A21- Hess	7.0	239	400			170			30		570	0.42	1154		451	1150	240	27.0	140.9	26.2	1/2 - 3

The Concrete Engineer reviews the Contractor's concrete mix design submittal and approves the materials and mix design based on compliance with the contract. Final approval for payment is based on satisfactory field placement and performance.

MnDOT Approval	

Comments:

Submit to: conc1off.dot@state.mn.us

Contractor Mix Design - Job Mix Formula (JMF)

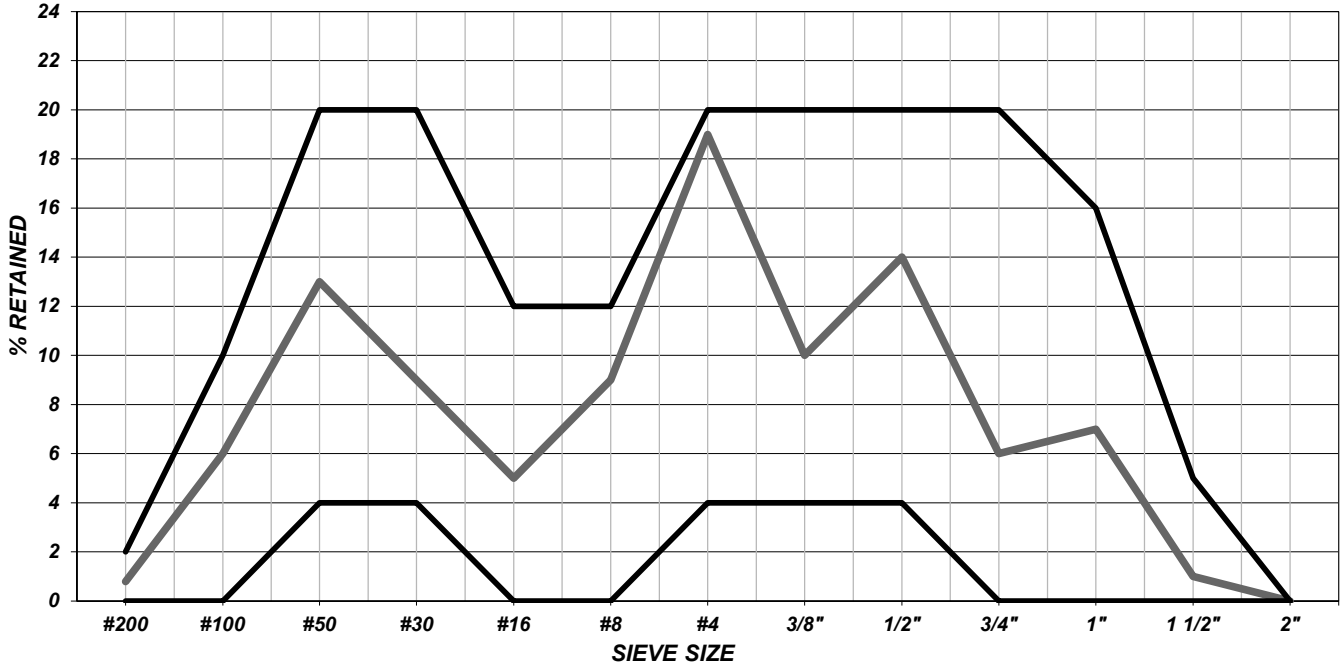
JMF

SP 8680-191

	FA #1	FA #2	CA #1	CA #2	CA #3	TOTAL % PASSING	WORKING RANGE	JMF WORKING RANGE		TOTAL % RETAINED
Agg. Size	Sand		3/4+	#67	CIA					
Prop. %	39		15	38	8	100%	LIMITS			
2"	100.0		100.0	100.0	100.0	100	± 5	95	100	0
1 1/2"	100.0		96.1	100.0	100.0	99	± 5	94	100	1
1"	100.0		45.2	100.0	100.0	92	± 5	87	97	7
3/4"	100.0		8.5	99.0	100.0	86	± 5	81	91	6
1/2"	100.0		0.4	64.4	100.0	72	± 5	67	77	14
3/8"	100.0		0.2	40.4	98.2	62	± 5	57	67	10
#4	99.0		0.0	4.1	32.9	43	± 5	38	48	19
#8	88.2			0.0	0.8	34	± 4	30	38	9
#16	74.4				0.1	29	± 4	25	33	5
#30	50.7					20	± 4	16	24	9
#50	17.0					7	± 3	4	10	13
#100	2.7					1	± 2	0	3	6
#200	0.4		0.0			0.2	≤ 1.6	0.0	1.6	1

Mix #
3A21- Hess

Well-Graded Aggregate Optional Incentive - % Retained Gradation Band



Coarse Sand % Retained (#8 through #30)
23
Greater than 15%, generally enhances cohesion of the mix.

Fine Sand % Retained (#30 through #200)
29
Between 24-34%, generally enhances workability of the mix.

July 26, 2022

Aggregate Industries
2815 Dodd Road, Suite 101
Eagan, MN 55121

Attn: Mr. Mark Bintzler

RE: Mix 3A21-RGSC Final Report of Trial Batching and Concrete Testing
2022 MnRoad
AET Project No. P-0010007

Dear Mr. Bintzler:

Materials arrived from Aggregate Industries at American Engineering Testing, Inc. (AET) the week of June 20, 2022. The trial batching was performed on June 23, 2022. The mix proportions used were per the standard MnDOT mix design report form provided by you. Concrete batching was conducted in accordance with the ASTM C192/C192M-19, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory."

The following testing was performed:

- SAM (AASHTO TP 118)
- Air Content (AASHTO T 152, ASTM C231/C231M-17a)
- Unit Weight (AASHTO T 121, ASTM C138/C138M-17a)
- Slump (AASHTO T 119)
- Box Test (AASHTO TP 137)
- Set Time (ASTM C403/C403M-16)
- Compressive Strength (AASHTO T 22, ASTM C39/C39-M-21)
- Flexural Strength (AASHTO T 97, ASTM C78/C78M-21)
- Estimating Concrete Strength by the Maturity Method (MnDOT Specification 2461.3G.6)

Sincerely,
American Engineering Testing
An AASHTO Accredited Laboratory – Aggregates, Cement & Concrete

AET Representative:

Daniel M. Vruno, PE
Principal Engineer
Construction Materials
Evaluation and Research
dvruno@teamAET.com
Phone: 651-659-1334

AET Representative:

Patrick Barnhouse, PE
Manager
Construction Materials
Evaluation and Research
pbarnhouse@teamAET.com
Phone: 651-999-1772

AET Project No:	P-0010007	**AET Project Mgr.:**	D. Vruno
Project:	2022 MnRoad	**AET Engineer:**	D. Vruno
Client:	Aggregate Industries, US	**Approved:**	P. Barnhouse
Contact:	Mr. Mark Bintzler	**Report Date:**	July 26, 2022

MIX DESIGN SUMMARY

	Mix 3A21-RGSC
Type IL (10) Portland Cement, Holcim, St. Genevieve (lb/yd^3)	400
Class F Fly Ash, Boral Resources, Coal Creek (lb/yd^3)	170
Fine Aggregate, Elk River Sand (lb/yd3)	1,171
Coarse Aggregate, Elk River CIA (lb/yd^3)	244
Coarse Aggregate, Elk River #67 (lb/yd3)	1,167
Coarse Aggregate, Empire 3/4"+ (lb/yd3)	457
Water (lb/yd^3)	228
Air Entrainer, Sika Air 260 (oz/cwt)	1.0
Retarder Sikatard 440 (oz/cwt)	1.1
High-Range Water Reducer, Sika, VISCOCRETE-1000 (oz/cwt)	2.0
Water to Cementitious Ratio	0.40

Fresh Properties	
Unit Weight (lb/ft^3)	142.4
Slump (in)	2.0
Air Content (%)	6.8
Temperature (°F)	74
Sam	0.24
Box Test	1,1,1,1 no edge slump
Initial Setting Time (hrs: min.)	6:27
Final Setting Time (hrs: min.)	7:55

Notes:

1. All test specimens were fabricated at AET on June 23, 2022.

550 Cleveland Avenue North | Saint Paul, MN 55114
Phone (651) 659-9001 | (800) 972-6364 | Fax (651) 659-1379 | teamAET.com | AA/EEO

AET Project No:	P-0010007	**AET Project Mgr.:**	D. Vruno
Project:	2022 MnRoad	**AET Engineer:**	N. Ciavarella
Client:	Aggregate Industries, US	**Approved:**	D. Vruno
Contact:	Mr. Mark Bintzler	**Report Date:**	July 26, 2022

TEST RESULT SUMMARY FOR MIX ID: 3A21-RGSC

ASTM C39, Compressive Strength

	Specimen A	Specimen B	Specimen C	**Average**
1 day, psi	2,090	1,890	2,090	**2,010**
3 day, psi	3,100	3,280	3,320	**3,230**
4 day, psi	3,270	3,300	3,360	**3,310**
7 day, psi	3,400	3,360	3,270	**3,340**
28 day, psi	5,010	4,800	x	**4,910**

ASTM C78, Flexural Strength

	Specimen A	Specimen B	**Average**
28 day, psi	680	670	**675**

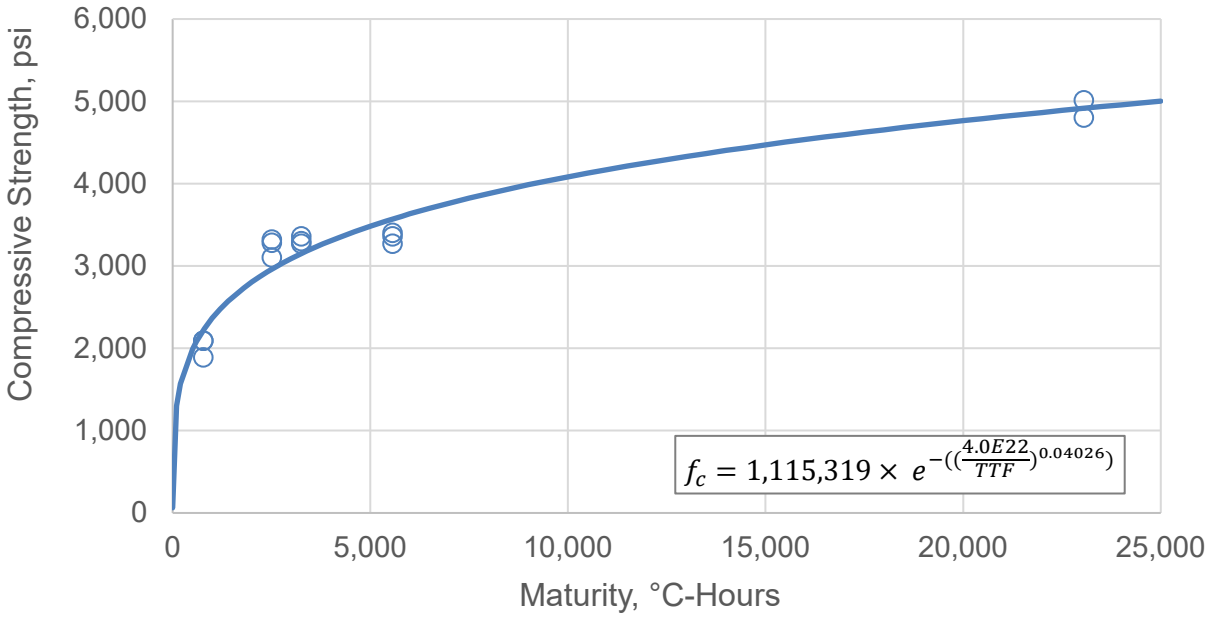
Notes:
1. All test specimens were fabricated at AET on June 23, 2022.
2. The test results represent the specimens tested and the methods specified.

550 Cleveland Avenue North | Saint Paul, MN 55114
Phone (651) 659-9001 | (800) 972-6364 | Fax (651) 659-1379 | teamAET.com | AA/EEO

AET Project No.:	P-001007	**AET Project Mgr.:**	D. Vruno
Project:	2022 MnRoad	**AET Project Eng.:**	D. Vruno
Client:	Aggregate Industries	**Approved:**	P. Barnhouse
Contact:	Mr. Mark Bintzler	**Report Date:**	7/26/2022

COMPRESSIVE STRENGTH VERSUS MATURITY FOR MIX ID: 3A21-RGSC

Age (days)	TTF (°C-Hours)	Specimen	Compressive Strength (psi)	**Average Strength (psi)**
1	783	1	2,090	**2,010**
		2	1,890	
		3	2,090	
3	2515	1	3,100	**3,230**
		2	3,280	
		3	3,320	
4	3260	1	3,270	**3,310**
		2	3,300	
		3	3,360	
7	5564	1	3,400	**3,340**
		2	3,360	
		3	3,270	
28	23054	1	5,010	**4,910**
		2	4,800	



Notes:

1. All test specimens were fabricated at AET on June 23, 2022.
2. Maturity curve was obtained with compressive strength results up to approximately 28 days.
3. The test results represent the specimens tested and the methods specified.
4. TTF refers to the time-temperature Nurse-Saul maturity values.

550 Cleveland Avenue North | Saint Paul, MN 55114
Phone (651) 659-9001 | (800) 972-6364 | Fax (651) 659-1379 | teamAET.com | AA/EEO

HOLCIM

Brand: OneCem
Material: Blended Cement
Type: IL(8) MS

Material Certification Report

Test Period: 1-Aug-2022 to 31-Aug-2022
Date Issued: 15-Sep-22

Certification

This cement meets the specifications of ASTM C595 and AASHTO M240 for Type IL cement.

General Information

Supplier:	Holcim (US) Inc.	Source Location:	Ste. Genevieve Plant
Address:	8700 West Bryn Mawr Ave Chicago, IL 60631		2942 US Highway 61 Bloomsdale, MO 63627
Contact:		Contact:	Ben Kist / (636) 524-8197

The following is based on average test data during the test period. The data is typical of product shipped from this source; individual shipments may vary.

Test Data on ASTM Standard Requirements

Chemical			Physical		
Item	**Limit [1]**	**Result**	**Item**	**Limit [1]**	**Result**
Sulfate as SO3 (%)	3.0 max[2]	3.20	+45 µm (No. 325) Sieve (%)	-	1.8
Loss on Ignition (%)	10.0 max	3.60	Blaine Fineness (m²/kg)	-	442
$CaCO_3$ in Limestone (%)	70 min	89	Density (g/cm³) (Specific Gravity)	-	3.12
			Autoclave Expansion (%) (C151)	-0.20 to +0.80	0.03
			Initial Vicat (minutes)	45-420	90
			Air Content (%)	12 max	6
			Compressive Strength Mpa (psi)		
			3 day	13.0 (1890) min	33.0 (4790)
			7 day	20.0 (2900) min	38.8 (5630)
			28 day (previous month's data)	25.0 (3620) min	46.5 (6750)
			Mortar Bar Expansion (%) (C1038)	0.02	0.007

Test Data on ASTM Optional Requirements

Chemical			Physical		
Item	**Limit [1]**	**Result**	**Item**	**Limit [1]**	**Result**
Equivalent Alkalies (%)	-	0.50			

Notes (*1-9)

1 - Dashes in the Limit / Result columns mean Not Applicable.
2 - It is permissible to exceed the specification limit provided that ASTM C1038 Mortar Bar Expansion does not exceed 0.020% at 14 days.
This data may have been reported on previous mill certificates.

Benjamin Kist,
Quality Manager

ECOMATERIAL TECHNOLOGIES

Materials Testing & Research Facility
2650 Old State Hwy 113
Taylorsville, GA 30178
770-684-0102

ASTM C618 / AASHTO M295 Testing of Coal Creek Station Fly Ash

Sample Date: 7/1 - 7/31/22
Report Date: 9/12/2022
Sample Type: Monthly
MTRF ID: 1608CC
Sample ID: MnDOT Split

Chemical Analysis	Results		ASTM Limit Class F / C	AASHTO Limit Class F / C
Silicon Dioxide (SiO2)	51.32	%		
Aluminum Oxide (Al2O3)	15.45	%		
Iron Oxide (Fe2O3)	5.71	%		
Sum (SiO2+Al2O3+Fe2O3)	72.48	%	50.0 min	50.0 min
Sulfur Trioxide (SO3)	0.67	%	5.0 max	5.0 max
Calcium Oxide (CaO)	14.10	%	18.0 max / >18.0	18.0 max / >18.0
Magnesium Oxide (MgO)	4.43	%		
Sodium Oxide (Na2O)	2.96	%		
Potassium Oxide (K2O)	2.30	%		
Total Alkali (Sodium Oxide Equivalent)	4.5	%		
Moisture	0.04	%	3.0 max	3.0 max
Loss on Ignition	0.10	%	6.0 max	5.0 max
Available Alkalies, as Na2Oe	1.62	%	Not Required	1.5 max*
				**when required by purchaser*
Physical Analysis				
Fineness, % retained on 45-µm sieve	20.68	%	34 max	34 max
Fineness Uniformity	1.2	%	±5 max	±5 max
Strength Activity Index - 7 or 28 day requirement				
7 day, % of control	84	%	75 min	75 min
28 day, % of control	93	%	75 min	75 min
Water Requirement, % control	93	%	105 max	105 max
Autoclave Soundness	-0.01	%	0.8 max	0.8 max
Density	2.54	g/cm3		
Density Uniformity	0.2	%	±5 max	±5 max

Christy Sieg
Lab Manager

AASHTO ACCREDITED

ASH GROVE CEMENT COMPANY

Quanity (tons):
Trailer/Car:
Shipped:

16215 Highway 50
Louisville, Nebraska 68037
Phone: 402-234-2415
FAX: 402-234-4825

Type IP (30)
Duracem® F

Date: 3/5/2021
Production Period: 12/11/2021

The following information is based on average test data during the production period. The data is typical of cement shipped from the Louisville, Nebraska plant. Individual shipments may vary.

STANDARD REQUIREMENTS
ASTM C595

CHEMICAL

Item	A.S.T.M. Test Method	Spec. Limit	Test Result
SiO_2 (%)	C114	*A*	31.1
Al_2O_3 (%)	C114	*A*	13.0
Fe_2O_3 (%)	C114	*A*	3.1
CaO (%)	C114	*A*	45.6
MgO (%)	C114	6.0 max	1.8
SO_3 (%)	C114	4.0 max	2.0
Loss on ignition (%)	C114	5.0 max	1.9
Na_2O (%)	C114	*A*	0.09
K_2O (%)	C114	*A*	0.59
Equivalent alkalies (%)	C114	*A*	0.48

PHYSICAL

Item	A.S.T.M. Test Method	Spec. Limit	Test Result
Air content of mortar (volume %)	C185	12 max	9
Fineness			
Air permeability (m^2/kg)	C204	*A*	686
450 mesh (%)		*A*	98.9
Autoclave expansion (%)	C151	0.80 max	
Autoclave contraction (%)	C151	0.20 max	
Compressive strength (psi)			
1 Day	C109	*A*	2110
3 Days	C109	1890 min	3610
7 Days	C109	2900 min	4700
28 Days	C109	3620 min	*7210*
Time of setting (minutes) (Vicat)			
Initial: Not less than	C191	45	113
Not more than		420	285
Sulfate resistance[1]	C1012	0.10	C
Specific Gravity	C188		2.90
Heat of hydration (cal/g)	C186		
7 Days		*B*	
Mortar expansion with Elkhorn River aggregate (%), 30 day[2]	C1567	0.10	0.04

[1] *Optional requirement*
[2] *N.D.O.R. specification*
A = Not applicable.
B = Test result represents most recent value and is provided for information only.
C = Test results for this period not available.

We certify that the above described cement, at the time of shipment, meets the chemical and physical requirement of the ASTM C595/C595M AASHTO M240 including the optional (HS) high sulfate resistance.

Signature:

Amanda Dorsey
Chief Chemist

MILL TEST REPORT

Month of Issue: October 2022
CaptureCrete SCM
Source: NV
Supplier: CARBON LIMIT CO.
Batch #:1
Received: July 2022

CHEMICAL ANALYSIS	COMPOSITION	LIMIT	ASTM Class F
Silicon Dioxide (SiO_2)	57.41%		
Aluminum Oxide (Al_2O_3)	10.51%		
Iron Oxide (Fe_2O_3)	0.85%		
Sum of Constituents ($SiO_2 + Al_2O_3 + Fe_2O_3$)	68.77%	Min.	50.0%
Calcium Oxide	6.29%	Max.	18.0%
Magnesium Oxide (MgO)	0.53%		
Sulfur Trioxide (SO_3)	1.18%	Max.	5.0%
Sodium Oxide (Na_2O)	2.85%		
Potassium Oxide (K_2O)	3.21%		
Sodium Oxide Equivalent ($Na_2O + 0.658\ K_2O$)	4.96%		
TiO_2	0.26%		
Loss On Ignition	16.41%	Max.	6.0%
PHYSICAL ANALYSIS			
Fineness, % Retained on #325	40.9%	Max.	34%
Strength Activity Index			
7 days, % of control	94%	Min.	75%
28 days, % of control	115%	Min.	75%
Water Requirement, % of control	108%	Max.	105%
Density, g/cm^3	1.96		

Notes: CaptureCrete SCM covered by this report does not comply with the current specification for: ASTM C618: Class F fly ash. As this novel SCM does not fall under any of the existing ASTM standards for SCM, it is compared with ASTM C618: Class F fly ash. It may fall under New Standard Specification for SCM for Use in Concrete which is in the balloting process at ASTM.

Report Created: March 9,2023

AN AUTHORIZED MANUFACTURER OF POZZOTIVE®

URBAN MINING CT POZZOTIVE® GROUND GLASS POZZOLAN CERTIFICATION REPORT

REPORT OF POZZOLAN ANALYSIS

Plant: Urban Mining CT Beacon Falls, CT
Date: Thursday, December 15, 2022
Supplier: Urban Mining CT Beacon Falls, CT
Product Type: Type GS Ground Glass Pozzolan
Sample Type: Composite
Sampling Period: November 2022

Chemical Composition (mass %)	Result	ASTM C1866 Limits Type GS
Silicon Oxide (SiO2)	72.30	60 min.
Aluminum Oxide (Al2O3)	1.80	5 max.
Calcium Oxide (CaO)	10.68	15 max.
Iron Oxide (Fe2O3(T))	0.30	1 max.
Sulfur Trioxide (SO3)	0.11	1 max.
Total Alkalis, Na2Oeq	13.33	15 max.
Moisture Content	0.07	0.5 max.
Loss on Ignition	0.27	0.5 max.

Physical Tests		
Fineness		
Retained on 45-m (No. 325) sieve (%)	0.0	5 max.
Strength Activity Index		
Percentage of Control @ 7 days (%)	87	75 min.
Percentage of Control @ 28 days (%)	93	85 min.
Water Requirement (% of Control)	93%	Report Only
Relative Density	2.54	Report Only

This certifies that this sample meets all of the requirements of ASTM C1866 and ASTM C618

SUPPLEMENTARY OPTIONAL CHEMICAL AND PHYSICAL REQUIREMENTS (ASTM C1866/C1866M Table 2 and Table 4)

Note: Specific surface shall indicate the test method used.

No tests requested

Signature: _____ Title: Plant General Manager

Anthony Criscuola

TETRA TECH

June 30, 2021

ISSUED FOR USE
FILE: 704-ENG.CGEO03900-01
Via Email: apoorv@carbonupcycling.com

Carbon Upcycling Technologies Inc.
9550 – 100 Street SE
Calgary, AB T2S 0A2

Attention: Mr. Apoorv Sinha

Subject: Fly Ash Testing – Summary Report
Battle River Fly Ash

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) has been testing the fly ash samples since 2020. This summary report is compiled to provide a comprehensive analysis of the properties of the fly ash sourced from Battle River and fly ash that underwent proprietary treatment developed by Carbon Upcycling Technologies Inc. (Carbon Upcycling).

2.0 PHYSICAL AND CHEMICAL TESTING

In June 2020 a report was issued by Tetra Tech with the results characterizing the fly ashes (virgin and treated). The testing was performed in accordance with Canadian Standards Association (CSA) A3003-18, CSA A3004-18, and American Society for Testing and Materials (ASTM) C311-18. The results are summarized in Table 1.

Table 1: Fly Ash Test Results – Battle River Fly Ash

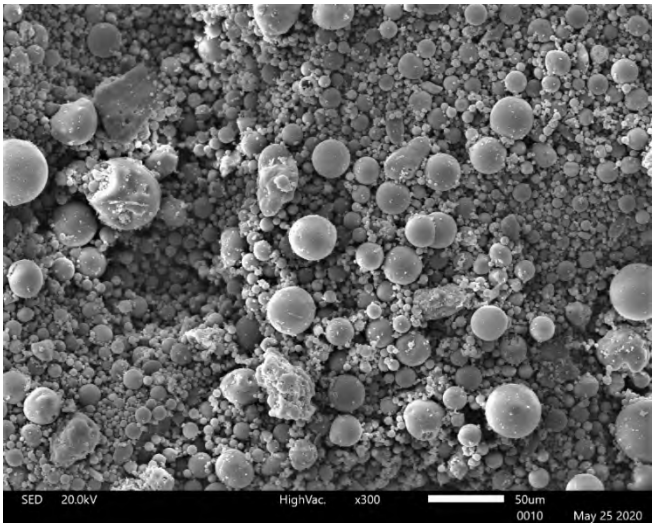
Test Description		Test Result			Specification Limit
		Untreated Ash	Low Treatment Ash	High Treatment Ash	
Moisture Content		1.2%	0.9%	0.4%	3% max. (CSA A3001-18) 3% max. (ASTM C618-12a)
Loss on Ignition		0.7%	1.4%	4.3%	8% max. (CSA A3001-18) 6% max. (ASTM C618-12a)
Specific Gravity		1.94 g/cm^3	2.52 g/cm^3	2.55 g/cm^3	--
Fineness, Retained on 45 µm Sieve		21.7%	4.9%	9.4%	34% max. (CSA A3001-18) 34% max. (ASTM C618-12a)
Air-Entrainment of Mortar		0.572%	0.459%	0.582%	--
Strength Activity	Water Requirement	97.5%	97.9%	96.7%	105% max. (ASTM C618-12a)
	7-day, % of control	85.0%	102.6%	133.6%	75% min. (ASTM C618-12a)
	28-day, % of control	98.2%	136.3%	149.6%	75% min. (CSA A3001-18) 75% min. (ASTM C618-12a)
Silicon Dioxide		59.4%	59.2%	57.4%	--
Aluminum Oxide		20.5%	20.1%	19.9%	--
Iron Oxide		4.9%	5.1%	4.8%	--
Calcium Oxide		6.0%	6.2%	5.8%	≤ 15% (CSA A3001-18)
Sulphur Trioxide		0.3%	0.3%	0.3%	5% max. (CSA A3001-18) 5% max. (ASTM C618-12a)

Tetra Tech Canada Inc.
Suite 110, 140 Quarry Park Blvd SE
Calgary, AB T2C 3G3 CANADA
Tel 403.203.3355 Fax 403.203.3301

The results indicate that the chemical composition due to the Carbon Upcycling treatment remains relatively unchanged. A more significant change was noted as an increase in specific gravity and an increase in fineness of treated ash. Of note is the increased strength activity at 7 days and 28 days for treated ash samples while the water requirement is unchanged.

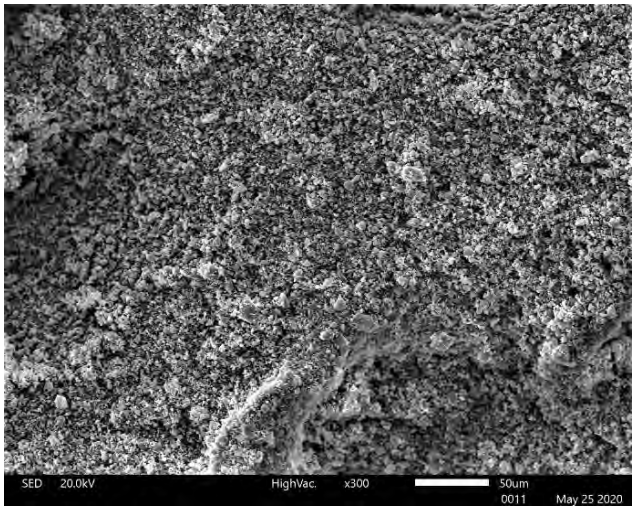
3.0 MICROSTRUCTURE OBSERVATIONS BY SEM

The fly ash was analysed under the scanning electron microscope (SEM) to determine how the change in fineness of the treated fly ash affects the microstructure. The untreated Battle River ash consists of predominantly spherical particles and some crushed spheres, typical for any source of fly ash (Micrograph 1).

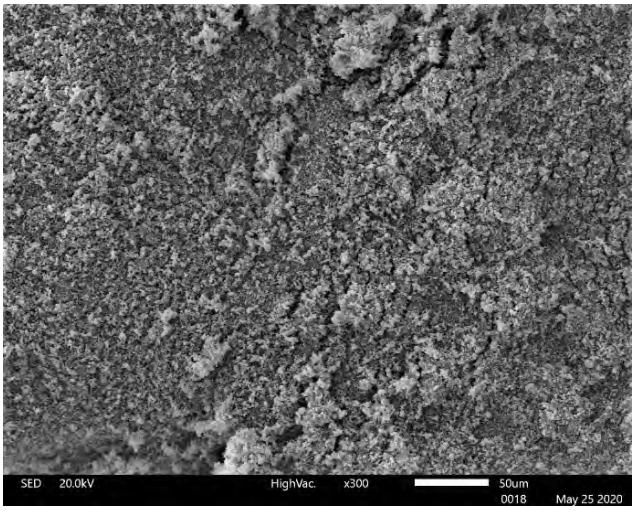


Micrograph 1: Magnification (Mag) 300x

A low treatment ash at the same magnification reveals a much finer microstructure (Micrograph 2) similar to the microstructure of the high treatment ash (Micrograph 3).

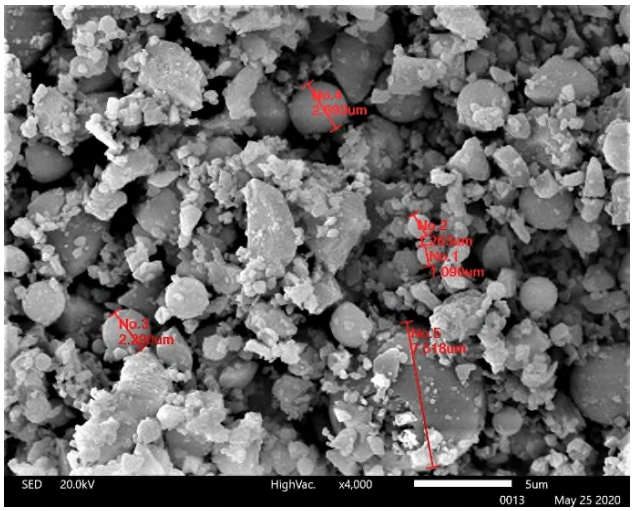


Micrograph 2: Mag 300x. Low Treatment

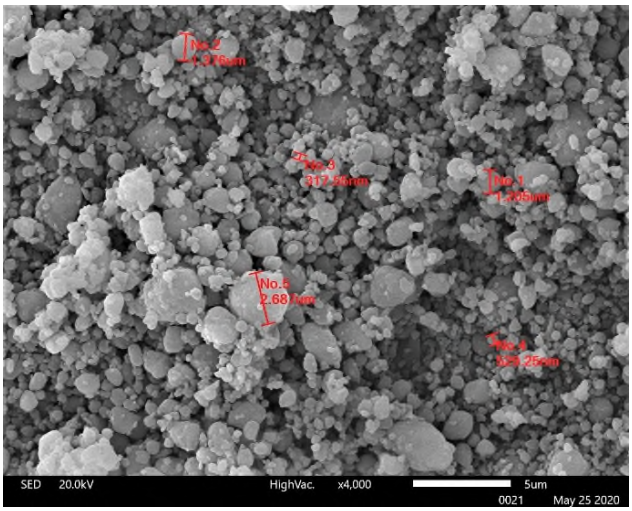


Micrograph 3: Mag 300x. High Treatment

The low treatment ash observed at 4000x magnification shows mostly crushed spheres with sharp edges and some unaffected smaller spheres (Micrograph 4). The high treatment ash is finer and consists mostly of crushed spheres with more rounded edges (Micrograph 5).



Micrograph 4: Mag 4000x. Low Treatment



Micrograph 5: Mag 4000x. High Treatment

SEM observations confirmed that the ash treatment results in much finer material that has an increased surface area and is expected to be more reactive than the untreated ash.

4.0 ALKALI-SILICA REACTIVITY (ASR)

In July 2020, Tetra Tech issued the report on mitigated accelerated ASR of mortar bars with 20% untreated and treated Battle River ash. The testing is done in accordance with Canadian Standards Association (CSA) A23.2-25A, the test method for detection of alkali-silica reactive aggregate by accelerated expansion of mortar bars, and CSA A23.2-28A, the test method for effectiveness of supplementary cementing materials to prevent alkali-silica reaction in mortar bars.

The results indicated that 20% untreated fly ash did not mitigate ASR. The supplementary cementing materials (untreated and treated Battle River ash) are considered effective in preventing alkali-silica reactions if the expansion at 14 days is less than 0.100%.

The low treatment and high treatment ash mitigated against ASR and expansion at 14 days was three times lower when compared with the unmitigated ash. The summary of results is presented in Table 2.

Table 2: Aggregate Analysis

Source	Aggregates Tested	14 Day Results (% Expansion and Remarks)
Spratt Quarry #2	Spratt aggregate with 20% Battle River untreated fly ash	0.151 – Mitigated
	Spratt aggregate with 20% Battle River low treatment fly ash	0.045 – Mitigated
	Spratt aggregate with 20% Battle River high treatment fly ash	0.051 – Mitigated

5.0 SULPHATE TESTING

Sulphate testing was conducted in accordance with ASTM C1012, Standard Test Method for Length Change of Hydraulic Cement Mortars Exposed to Sulphate Solution, and the expansion limits were applied in accordance with CSA A3000-18, Table 3.

5.1 Sulphate Testing at 20% Fly Ash Replacement

In May 2020 testing for expansion with 20% Battle River fly ash replacement commenced and the test was completed in June 2021. The results are attached. The results indicate that untreated and treated ash samples met the expansion limits at 26 weeks and 52 weeks, and the treated ashes showed lower expansions.

5.2 Sulphate Testing at 15% Fly Ash Replacement

In July 2020 sulphate testing with 15% Battle River ash was initiated and the testing is ongoing. The interim results are attached.

The results indicate that at 15% fly ash replacement, an untreated Battle River ash is trending to meet the CSA expansion limit at 52 weeks and low treatment and high treatment ash meet the 26 week limit and 52 week expansion limit. The expansion of the treated ash is half of the expansion of untreated ash.

5.3 Sulphate Testing at 30% Fly Ash Replacement

In July 2020 sulphate testing with 30% Battle River ash was initiated and the testing is ongoing.

A similar trend is noted at 30% Battle River ash replacement. The untreated Battle River ash is trending to meet the CSA expansion limit at 52 weeks and low treatment and high treatment ash meet the 26 week limit and 52 week expansion limit. The expansion of the treated ash is half of the expansion of untreated ash.

6.0 DISCUSSION

The Carbon Upcycling technology is a proprietary process and will not be reviewed. The testing results indicate that the low and high treatment of the Battle River ash results in altered physical characteristics of the ash and impacts the properties of concrete. The findings are summarized as follows.

- The upcycling process does not alter chemistry of the ash.
- The upcycling process densifies the ash; specific gravity is increased and the ash is finer. These findings were confirmed by SEM analysis; treated ash particles were predominantly crushed and only small fly ash spheres remained intact. In general, SCM that are finer are expected to be more reactive.
- The strength activity is increased at 7 days and 28 days when compared with the untreated Battle River ash.
- Based on the accelerated testing for ASR with a 20% fly ash replacement level, the untreated Battle River ash did not mitigate against ASR. Low level and high level treatment ash was effective in ASR mitigation and exhibited expansions that were three times smaller when compared with untreated ash.
- Low treatment and high treatment Battle River ash is effective in mitigation against sulphate attack at 15%, 20%, and 30% replacement levels.

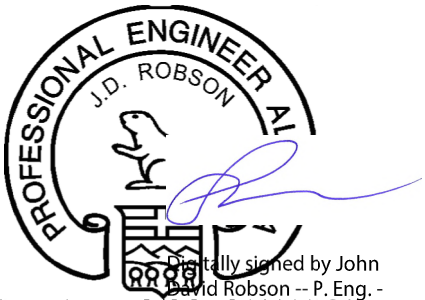
7.0 LIMITATIONS OF REPORT

This letter report and its contents are intended for the sole use of Carbon Upcycling Technologies Inc. and their agents. Tetra Tech Canada Inc. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the letter report when the letter report is used or relied upon by any party other than Carbon Upcycling Technologies Inc., or for any project other than the proposed development at the subject site. Any such unauthorized use of this letter report is at the sole risk of the user. Use of this letter report is subject to the terms and conditions stated in Tetra Tech's Services Agreement. Tetra Tech's Limitations on the Use of This Document are enclosed with this letter report.

8.0 CLOSURE

We trust the information provided meets your present requirements. However, should you have any questions, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.



FILE: 704-ENG.CGEO03900-01
FILE: 704-ENG.CGEO03900-01
FILE: 704-ENG.CGEO03900-01

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FILE: 704-ENG.CGEO03900-01
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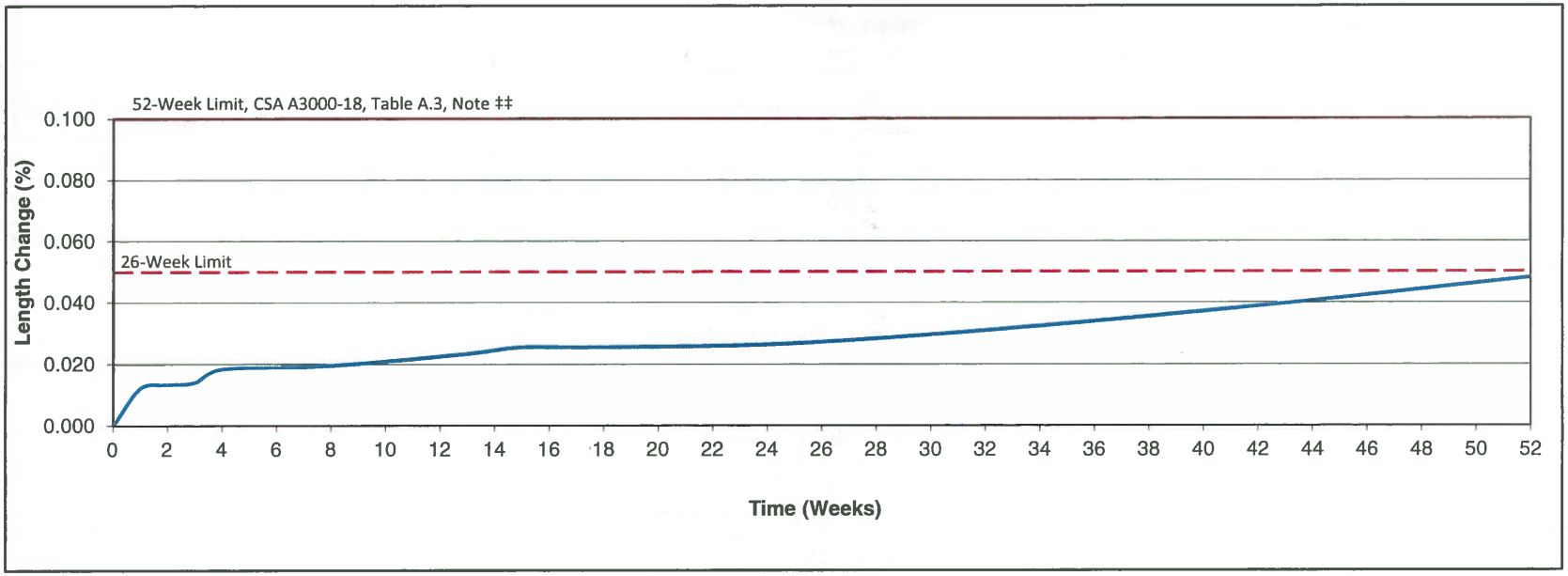
/mh

Attachments (4): Sulphate Expansion C4 to C6 at 52 Weeks (3 pages)
Sulphate Expansion C7 to C9 at 39 Weeks (3 pages)
Sulphate Expansion C10 to C12 at 39 Weeks (3 pages)
Tetra Tech's Limitations on the Use of This Document (2 pages)

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C4
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	May 20, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 20% Battle River Fly Ash (Untreated)



Remarks: Mississauga GU cement and 20% Battle River fly ash combination meet the CSA expansion limits at 26-weeks and 52-weeks.

Time (weeks)	Expansion (%) C4	Time (weeks)	Expansion (%) C4
0	0.000	13	0.023
1	0.012	16	0.026
2	0.013	18	0.026
3	0.014	26	0.027
4	0.019	39	0.036
8	0.020	52	0.048

Reviewed By: _____ P.Eng.

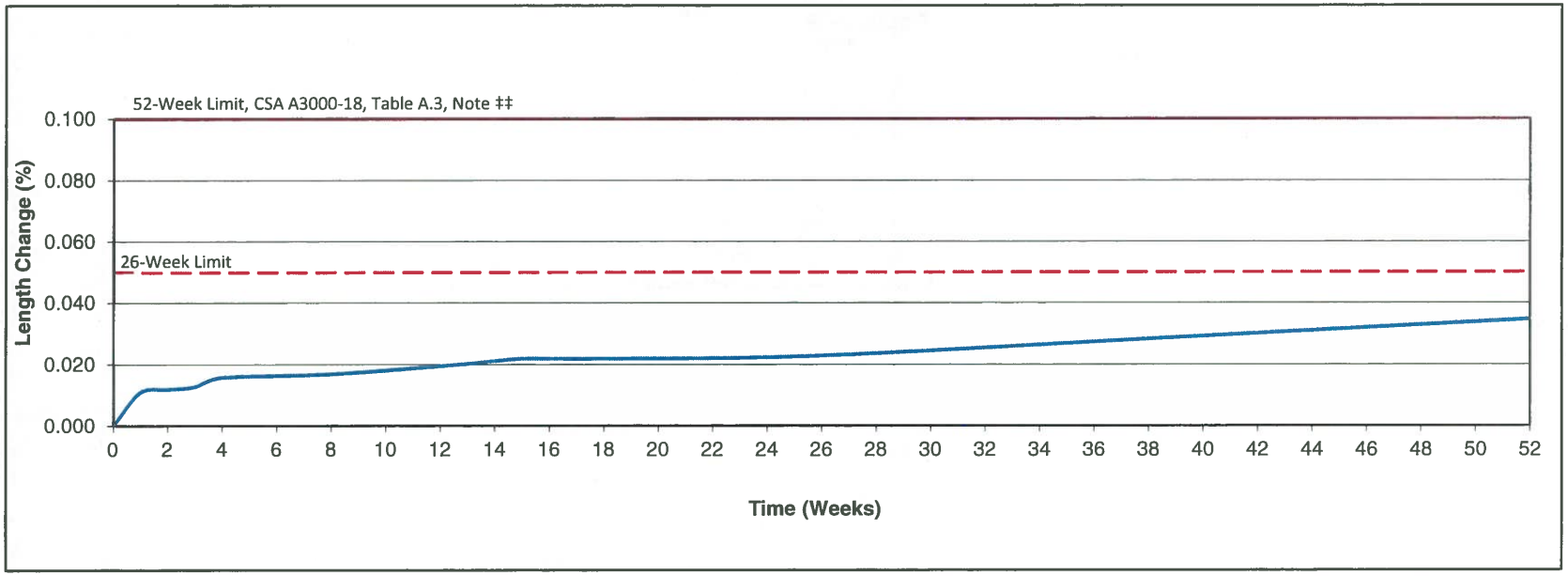
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C5
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	May 19, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 20% Battle River Fly Ash (Low Treatment)



Remarks: Mississauga GU cement and 20% Battle River fly ash (low treatment) combination meet the CSA expansion limits at 26 weeks and 52 weeks.

Time (weeks)	Expansion (%) C5	Time (weeks)	Expansion (%) C5
0	0.000	13	0.020
1	0.011	16	0.022
2	0.012	18	0.022
3	0.013	26	0.023
4	0.016	39	0.029
8	0.017	52	0.035

Reviewed By: _____ **P.Eng.**

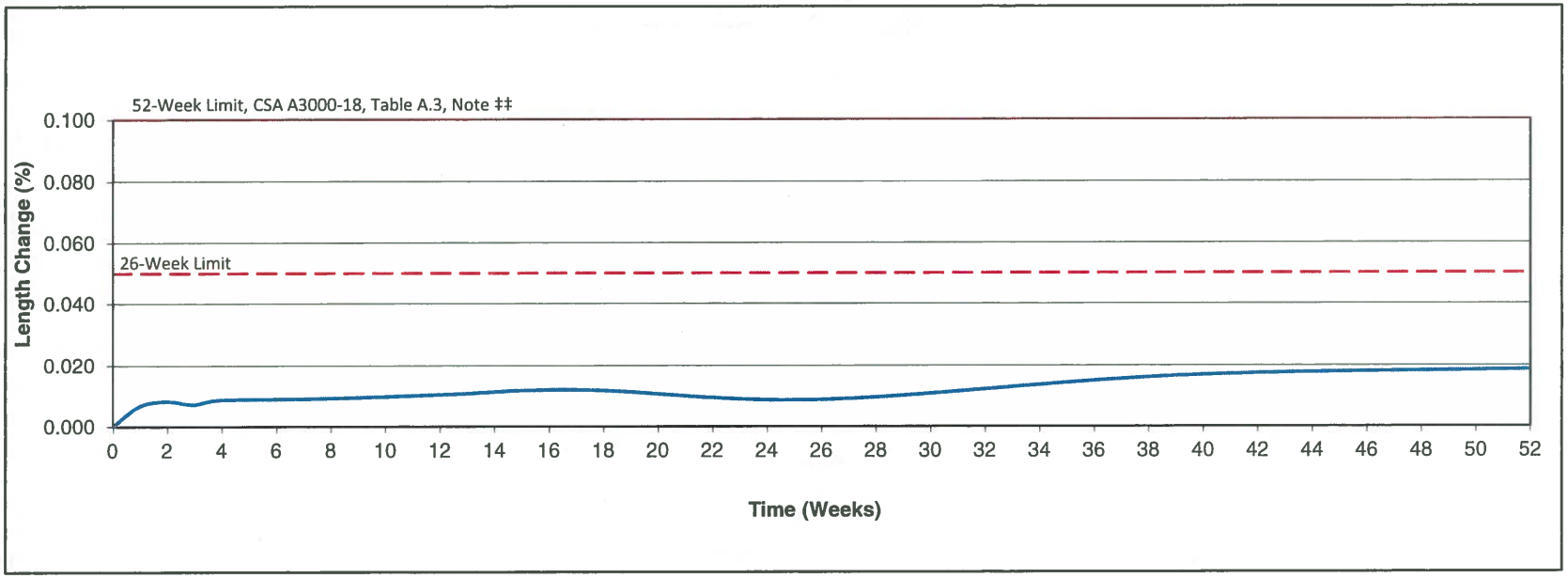
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C6
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	May 19, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 20% Battle River Fly Ash (High Treatment)



Remarks: Mississauga GU cement and 20% Battle River fly ash (high treatment) combination meet the the CSA expansion limits at 26-weeks and 52-weeks.

Reviewed By: _____ **P.Eng.**

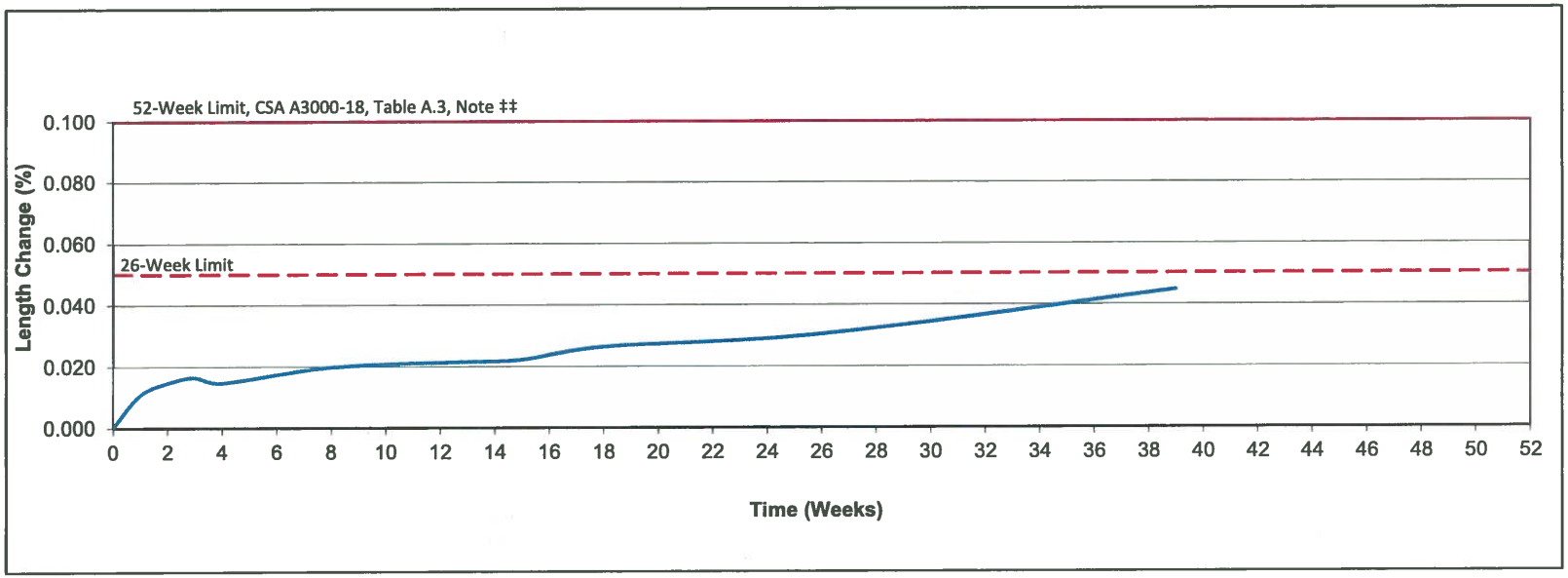
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

Time (weeks)	Expansion (%) C6	Time (weeks)	Expansion (%) C6
0	0.000	13	0.011
1	0.007	16	0.012
2	0.008	18	0.012
3	0.007	26	0.009
4	0.009	39	0.017
8	0.009	52	0.019

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C7
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 28, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 15% Battle River Fly Ash (Untreated)



Remarks:

Time (weeks)	Expansion (%) C7	Time (weeks)	Expansion (%) C7
0	0.000	13	0.022
1	0.011	16	0.022
2	0.015	18	0.026
3	0.017	26	0.031
4	0.015	39	0.045
8	0.020	52	-

Reviewed By: _____ **P.Eng.**

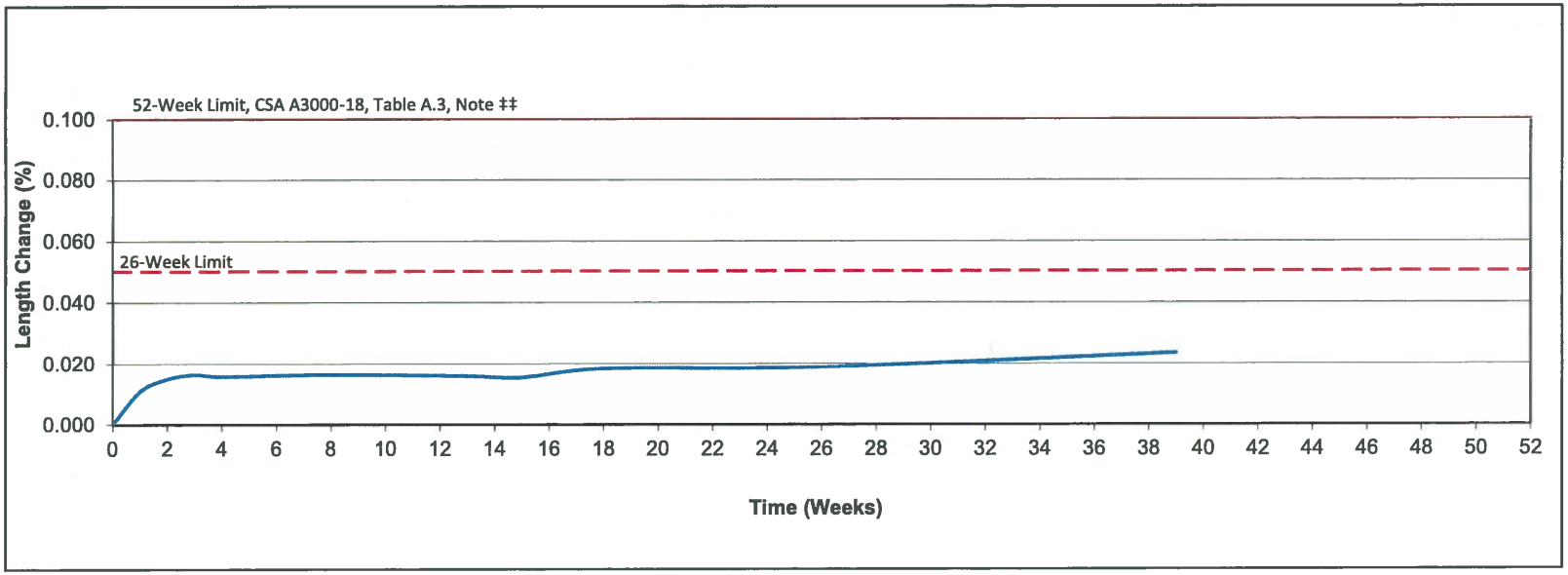
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C8
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 28, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 15% Battle River Fly Ash (Low Treatment)



Remarks:

Time (weeks)	Expansion (%) C8	Time (weeks)	Expansion (%) C8
0	0.000	13	0.016
1	0.011	16	0.016
2	0.015	18	0.019
3	0.017	26	0.019
4	0.016	39	0.024
8	0.017	52	-

Reviewed By: _____ P.Eng.

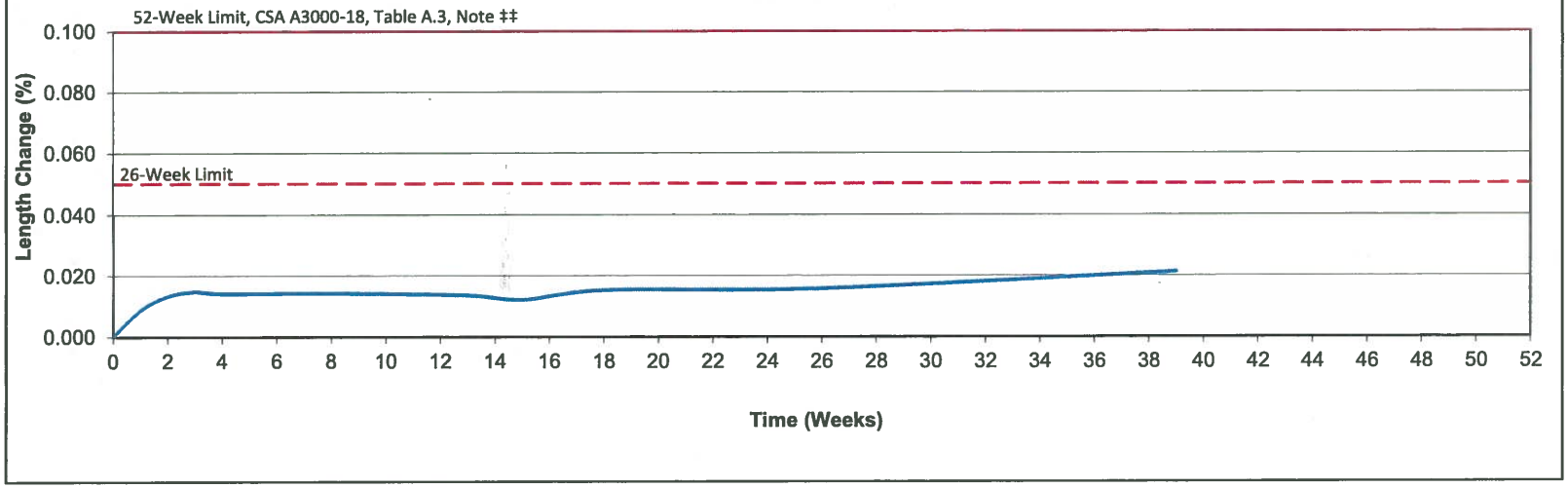
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C9
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 28, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 15% Battle River Fly Ash (High Treatment)



Remarks:

Time (weeks)	Expansion (%) C9	Time (weeks)	Expansion (%) C9
0	0.000	13	0.014
1	0.009	16	0.012
2	0.013	18	0.015
3	0.015	26	0.016
4	0.014	39	0.021
8	0.014	52	-

Reviewed By: _____ P.Eng.

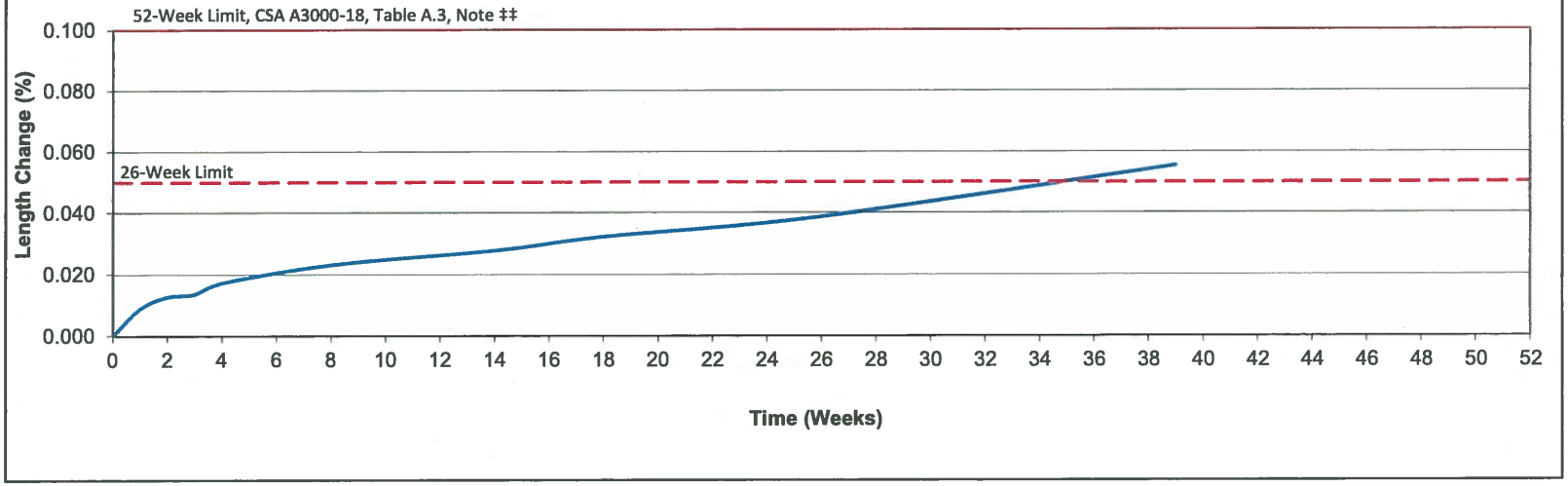
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C10
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 30, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 30% Battle River Fly Ash (Untreated)



Remarks:

Time (weeks)	Expansion (%) C10	Time (weeks)	Expansion (%) C10
0	0.000	13	0.027
1	0.009	16	0.029
2	0.013	18	0.032
3	0.014	26	0.039
4	0.017	39	0.056
8	0.023	52	-

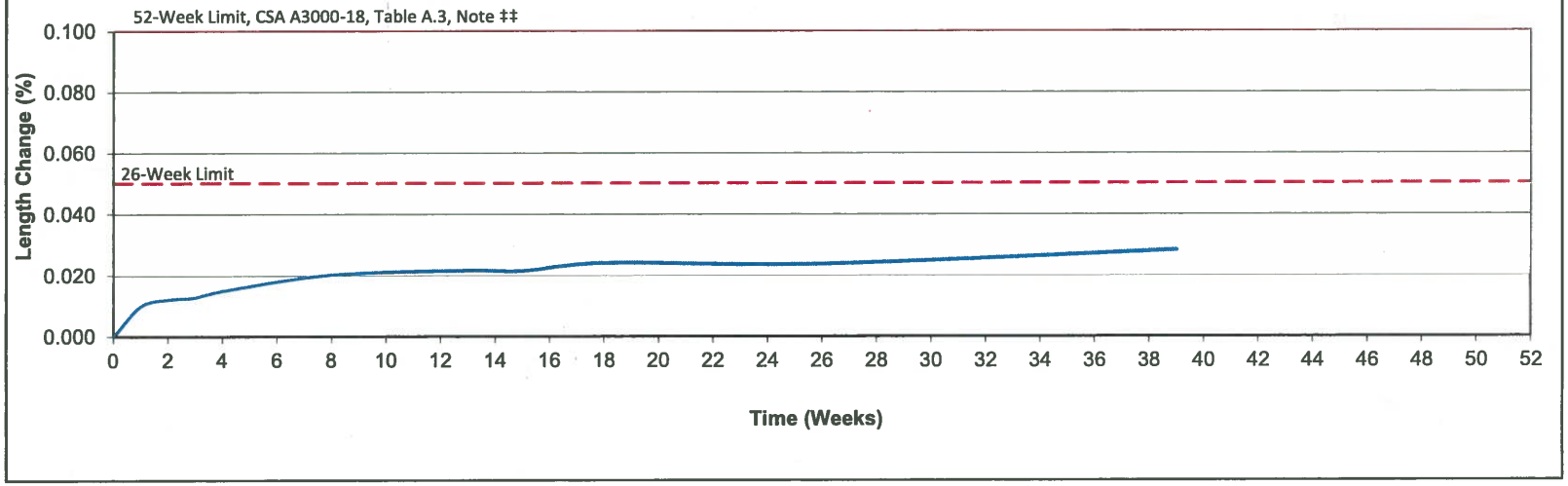
Reviewed By: _____ **P.Eng.**

Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C11
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 30, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 30% Battle River Fly Ash (Low Treatment)



Remarks:

Time (weeks)	Expansion (%) C11	Time (weeks)	Expansion (%) C11
0	0.000	13	0.022
1	0.010	16	0.022
2	0.012	18	0.024
3	0.013	26	0.024
4	0.015	39	0.029
8	0.020	52	-

Reviewed By: _____ **P.Eng.**

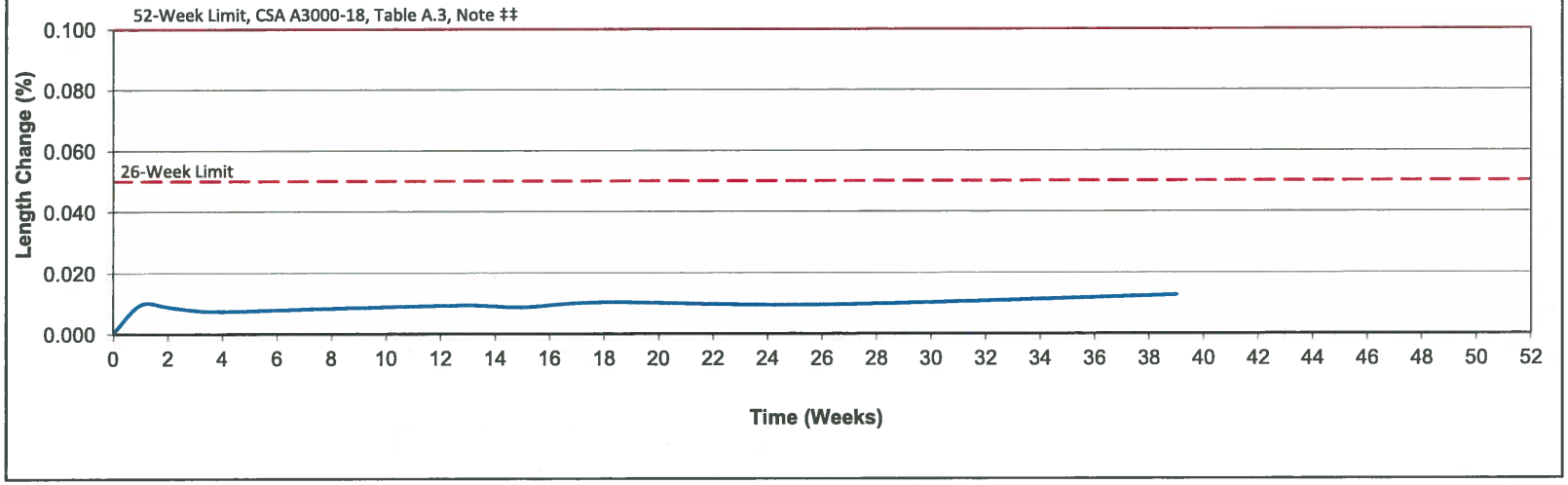
Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

Length Change of Hydraulic - Cement Mortars Exposed to Sulphate Solution

ASTM C1012

Project:	2020 Fly Ash Testing	**Sample No.:**	C12
Project No.:	704-ENG.CGEO03900-01	**Date Cast:**	July 30, 2020
Client:	Carbon Upcycling Technologies Inc.	**Tested By:**	KH/EM
Attention:	Apoorv Sinha	**Description:**	Mississauga GU with 30% Battle River Fly Ash (High Treatment)



Remarks:

Time (weeks)	Expansion (%) C12	Time (weeks)	Expansion (%) C12
0	0.000	13	0.009
1	0.010	16	0.009
2	0.009	18	0.010
3	0.008	26	0.010
4	0.007	39	0.013
8	0.008	52	-

Reviewed By: _____ **P.Eng.**

Office: 110, 140 Quarry Park Blvd. S.E. Calgary, AB T2C 3G3

TETRA TECH

LIMITATIONS ON USE OF THIS DOCUMENT

CONSTRUCTION MATERIALS ENGINEERING AND TESTING

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

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Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental, regulatory, or sediment and erosion issues associated with construction on the subject site.

1.8 VARIATION OF MATERIAL CHARACTERISTICS AND CONDITIONS

Observations and standardized sampling, inspection and testing procedures employed by TETRA TECH will indicate conditions of materials and construction activities only at the precise location and time where and when Services were performed. The Client recognizes that conditions of materials and construction activities at other locations may vary from those measured or observed, and that conditions at one location and time do not necessarily indicate the conditions of apparently identical material(s) at other locations and/or times.

Services of TETRA TECH, even if performed on a continuous basis, should not be interpreted to mean that TETRA TECH is observing, verifying, testing or inspecting all materials on the Project. TETRA TECH is responsible only for those data, interpretations, and recommendations regarding the actual materials and construction activities observed, sampled, inspected or tested, and is not responsible for other parties' interpretations or use of the information developed. TETRA TECH may make certain inferences based upon the information derived from these procedures to formulate professional opinions regarding conditions in other areas.

1.9 SAMPLING, OBSERVATION & TEST LOCATIONS

Unless specifically stated otherwise, the Scope of Services does not include surveying the Site or precisely identifying sampling, observation or test locations, depths or elevations. Sampling, observation and test locations, depths and elevations will be based on field estimates and information furnished by the Client and its representatives. Unless stated otherwise in the report, such locations, depths and elevations provided are approximate.

1.10 CONTRACTOR'S PERFORMANCE

TETRA TECH is not responsible for Contractor's means, methods, techniques or sequences during the performance of its Work. TETRA TECH will not supervise or direct Contractor's Work, nor be liable for any failure of Contractor to complete its Work in accordance with the Project's plans, specifications and applicable codes, laws and regulations. The Client understands and agrees that Contractor, not TETRA TECH, has sole responsibility for the safety of persons and property at the Project Site.

1.11 NOTIFICATION AND LEVEL OF SERVICE

Unless the Client requests or the building code requires full-time services, the Client understands that services provided by TETRA TECH are on an "On-Call" basis. The Client shall assume responsibility for adequate notification and scheduling of TETRA TECH services. TETRA TECH will make every reasonable effort to meet the Client's schedule, but will not guarantee service availability without direct confirmation from with the Client or their agent.

1.12 CERTIFICATIONS

The Client will not require TETRA TECH to execute any certification regarding Services performed or the Work tested or observed unless: 1) TETRA TECH believes that it has performed sufficient Services to provide a sufficient basis to issue the certification; 2) TETRA TECH believes that the Services performed and Work tested or observed meet the criteria of the certification; and 3) TETRA TECH has reviewed and approved in writing the exact form of such certification prior to execution of the Service Agreement. Any certification by TETRA TECH is limited to the expression of a professional opinion based upon the Services performed by TETRA TECH, and does not constitute a warranty or guarantee, either express or implied.

1.13 WEATHER AND PROTECTION OF MATERIALS

Performance of the Services by TETRA TECH and/or its designated subcontractor may be delayed or excused when such performance is commercially impossible or impracticable as a result of weather events, strikes, shortages or other causes beyond their reasonable control which may also impact cost estimates.

Excavation and construction operations expose materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations, and stockpiles, must be protected from the elements, particularly moisture, desiccation, frost action and construction activities.

1.14 CALCULATIONS AND DESIGN

Where TETRA TECH has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, TETRA TECH's client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by TETRA TECH's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of TETRA TECH.

1.15 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.16 SAMPLES

The Client will provide samples for testing (at the Client's expense). TETRA TECH will retain unused portions of samples only until such time as internal review is accomplished for intended purpose. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded. The duration of sample retention must be discussed in advance.

1.17 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design or testing has been completed. It is incumbent upon TETRA TECH's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by TETRA TECH or others, it will be referenced in the Construction Materials or Materials Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for this Report.

Appendix B: List of Tests Performed

MCTC Test Plan– MnROAD

Test Matrix

Tests per cell

- Fresh Concrete Properties (temp., slump, unit weight, air content) (one test per cell)
- Box test for workability (one test per cell)
- VKelly test for workability (one test per cell)
- Phoenix Water Content (one test per cell)
- Microwave (one test per cell)
- Determine paste content and plot combined aggregate gradation curve for each mixture
- Compressive strength cylinders (one set of 9 cylinders per test section) (7, 28, and 56 days)
- Flexural strength beams (two specimens per cell) (28 days)
- Modulus of Elasticity and Poissions Ratio (one specimen per cell) (28 days)
- One set of splitting tensile strength (two specimens per cell) (28 days)
- Coefficient of Thermal Expansion (one specimen per cell) (56 days and beyond)
- Calorimetry (one specimen per cell)
- Super Air Meter tests (one test per cell)
- 457 Samples (two tests per cell)
- Two extra specimens for any future need
- Permeability Related Tests

Alkali solution - Bucket

- Resistivity of bucket solution (at 1 d after preparation)
- 3x 4by8 cylinders - 60 specimens (20 buckets) – 40 specimens to be tested
  - Resistivity (7d, 28d, 56d, 91d, 120d)
  - Cylinders at 120d will be cut and be used for:

- 2 migration tests
- 2 water absorption (ASTM C1585) tests
- Chloride ponding

Limewater - Tank

- 3x 4by8 cylinders - 60 specimens (20 buckets) – 40 specimens to be tested
  - Resistivity (7d, 28d, 56d, 91d, 120d)
  - Cylinders at 120d will be cut and be used for:
    - 2 migration tests
    - 2 water absorption (ASTM C1585) tests
    - Chloride ponding

- Carbon Content??
  - 4 2x4 cylinders (mortar only) #4 sieve size – total 80

- Materials for later age testing
  - Raw materials would be sampled and sent to TFHRC by AET

Specimen Matrix

Tests	**Breakdown**	**Number of Specimens**	**Comments**
Compression	3x3x20	180	N/A
Flexural	2x20	40	N/A
MOE	3X20	60	N/A
CTE	1X20	20	N/A
Calorimeter	1x20	20	Small Cylinder (3x6)
C457	2x20	40	N/A
Bucket SR	3x20	60	N/A
Lime SR	3x20	60	N/A
Mortar Specimens	4x20	80	Small Cylinders (2x4)
Total Cylinders	N/A	**520**	**All sizes**
Total Beams	N/A	**40**	N/A

1

Concrete Property	Test Method	Test Name	MnDOT	AET Testing
AGGREGATE AND MIX PROPERTIES	**MnDOT Spec 3126, 3131 and 3137**	Concrete Aggregate Quality Testing	1 per fraction per plant (control mixes)	N/A
AGGREGATE AND MIX PROPERTIES	**PP84**	Paste Content and Gradation	1 per fraction per plant per week	N/A
PLASTIC CONCRETE TESTING	**C231/T152**	Air Content	N/A	1 per 50 cy (4), AET will use SAM for this testing also
PLASTIC CONCRETE TESTING	**TP 118**	SAM	N/A	1 per 100 cy (2) - SAM tests should be on the same sample as a C231 test
PLASTIC CONCRETE TESTING	**C457**	Hardened Air Content	N/A	1 hardened air on sample that had C231 and SAM including paste content
PLASTIC CONCRETE TESTING	**C138**	Unit Weight	N/A	1 per 50 cy (4)
PLASTIC CONCRETE TESTING	**T119**	Slump	N/A	1 per 50 cy (4)
PLASTIC CONCRETE TESTING	**C1064**	Temperature	N/A	1 per 50 cy (4)
PLASTIC CONCRETE TESTING	**PP84**	Box	N/A	1 per cell
PLASTIC CONCRETE TESTING	**PP84**	V-Kelly	N/A	N/A
PLASTIC CONCRETE TESTING	**T152**	Phoenix	N/A	N/A
PLASTIC CONCRETE TESTING	**T318**	Microwave	N/A	N/A
PLASTIC CONCRETE TESTING	N/A	Cementometer (MnDOT)	Research	N/A
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *As-built*	N/A	1 set per cell - do not break
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *1-day*	N/A	1 per 50 cy (4)
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *3-day*	N/A	1 per 50 cy (4)
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *7 day*	N/A	1 per 50 cy (4)
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *14 day*	N/A	1 per 50 cy (4)

Concrete Property	Test Method	Test Name	MnDOT	AET Testing
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *28 day*	N/A	1 per 50 cy (4)
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *42 day*	N/A	1 per 50 cy (4)
STRENGTH AND MATURITY	**C39**	Compressive (set of 2 - 6x12) - Laboratory Curing *56 day*	N/A	1 per cell
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *1-day*	N/A	1 per cell for CPR Only
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *3-day*	N/A	1 per cell
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *7 day*	N/A	1 per cell
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *14 day*	N/A	N/A
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *28 day*	N/A	1 per cell
STRENGTH AND MATURITY	**C78**	Flexural (set of 2) - Laboratory Curing *56 day*	N/A	1 per cell
STRENGTH AND MATURITY	**C1074/MnDOT**	Maturity	Research will install sensors and monitor	N/A
FIBERS	**C1609**	Residual Flexural Strength *14 day*	N/A	1 set per cell for Cell 2226 & 2227
FIBERS	**C1609**	Residual Flexural Strength *28 day*	N/A	1 set per cell for Cell 2226 & 2227
TRANSPORT	**T358**	Resistivity 1, 3, 7, 14, 28, 42, 56 days	N/A	Test compressive strength specimens for resistivity with Wenner probe prior to breaking - surface resistivity on all
TRANSPORT	**C1202**	Rapid Chloride Permeability (*56-days*)	N/A	1 per cell
TRANSPORT	**C1876-19**	Bulk Resistivity (*7, 28, 56, 91, 120 days*) Method 1: Alkali Solution - Bucket Method 2: Limewater - Tank 1 set of 3 - 4x8 cylinders per method	N/A	N/A
TRANSPORT	**PP84**	Formation Factor	N/A	N/A
DURABILITY ASTM C 666	**C666**	Freeze-Thaw	N/A	1 set per cell (300 cycles)

Concrete Property	Test Method	Test Name	MnDOT	AET Testing
JOINTS	**PP84**	Time to Critical Saturation	N/A	N/A
JOINTS	**T365**	Deicing Salt Damage	N/A	N/A
ASR	**C1293**	Concrete Prism	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol
ASR	**T380**	Miniature Concrete Prism	Sample Raw Materials during construction	AET doesn't have testing capability currently for this test
ASR	**C1567**	Mortar Bar	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol
ASR	**C1260**	Mortar Bar (IL Cement Only)	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol
MECHANICAL	**C469**	Poissons and Elastic Modulus	N/A	N/A
MECHANICAL	**T336**	Coefficient of Thermal Expansion	N/A	N/A
MECHANICAL	**C157**	Drying Shrinkage (35 days)	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol
CARBON CAPTURE	N/A	Carbon Sequestration - NIST Carbon Uptake, Thermal Gravimetric Analysis - Iowa State, Carbon Sequestration - Turner Fairbanks	N/A	4 - 4 Wet-sieved sample (reduced cylinder size (2x4's are fine) and 2 regular 4x8 cylinder, all lab cured, MnDOT will provide further guidance prior to sampling for ISU/NIST
CEMENTITIOUS MATERIAL TESTING	N/A	Chemical Composition - Chemical Analysis (XRD and XRF)	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol on each of the raw additive materials
CEMENTITIOUS MATERIAL TESTING	N/A	ASTM C1897 on SCMs Pore solution expression, chemical analysis, pH and electrical resistivity Possibly: Small ring test (on paste) ASTM C1698 (on paste) Set time Chloride binding	Sample Raw Materials during construction - luca will add TGA quantity to this	N/A
CEMENTITIOUS MATERIAL TESTING	**C1038**	Expansion of Mortar Bars stored in water	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol on each of the raw material combinations
CEMENTITIOUS MATERIAL TESTING	**C1012**	Expansion of Mortar bars in sulfate solution at 12 months	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol on each of the raw cementitious material combinations

Concrete Property	Test Method	Test Name	MnDOT	AET Testing
CEMENTITIOUS MATERIAL TESTING	**C311**	Fly Ash or Natural Pozzolans	Sample Raw Materials during construction	Determine quantity of materials needed for testing and follow test protocol on each of the raw additive materials that apply
CEMENTITIOUS MATERIAL TESTING	**C1679**	Semi-adiabatic calorimetry	N/A	N/A
CEMENTITIOUS MATERIAL TESTING	**C403**	Set Time	N/A	N/A

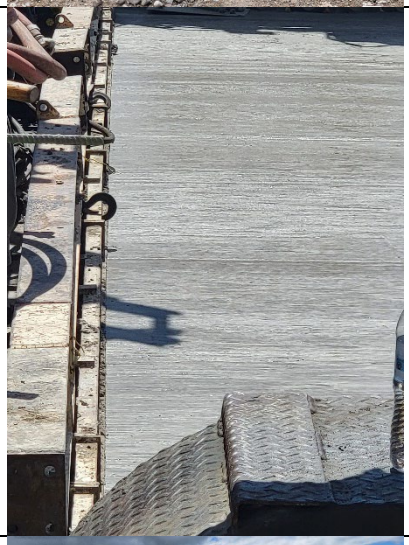
Appendix C: Representative Construction Photos

Cell 2209 Ultra High

Cell 2210 Carbon Cure w/CO2 Injection

Cell 2211 Carbon Cure Control w/CO2 Injection

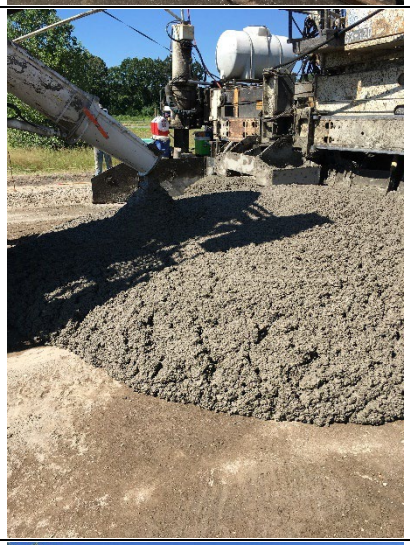
Cell 2212 Carbon Cure w/o CO2 Injection



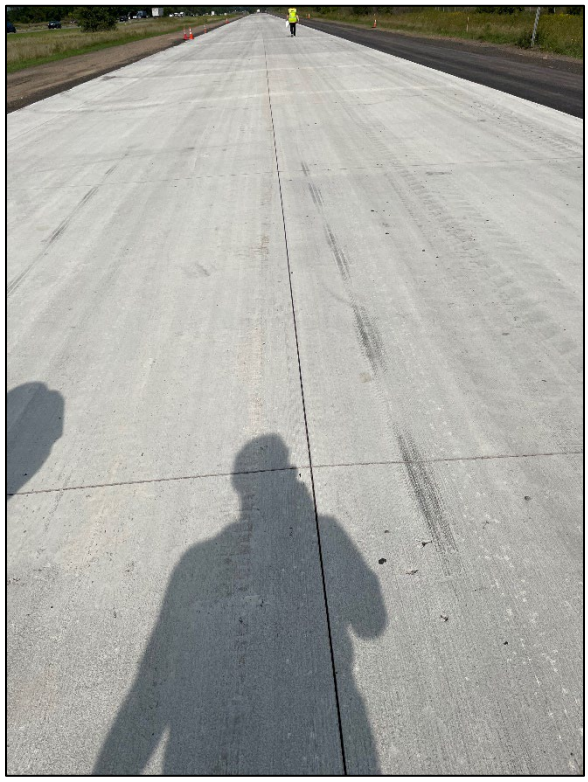
Cell 2213 Carbon Upcycling

Cell 2214 Ash Grove IP(30)

Cell 2215 Urban Mining

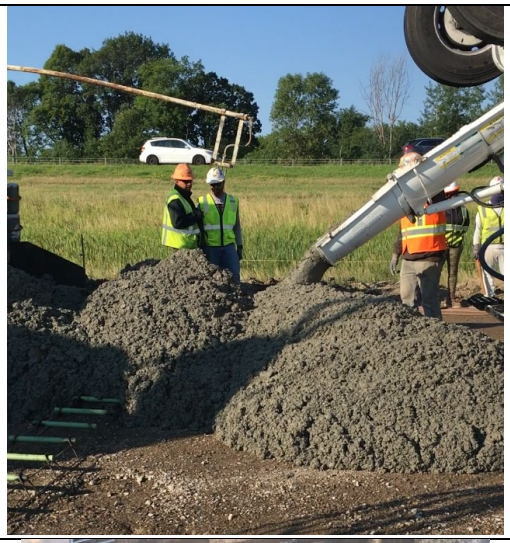


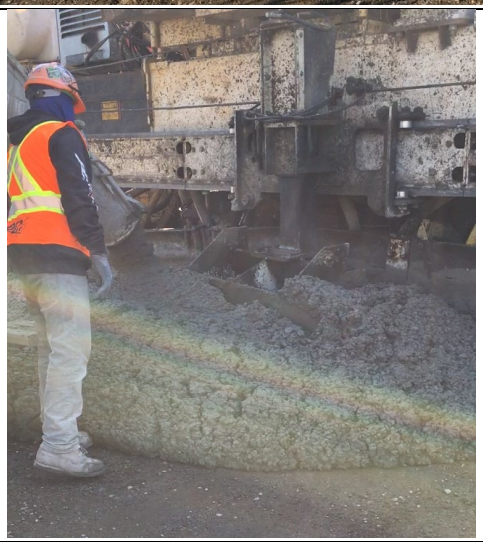
Cell 2216 Terra CO2



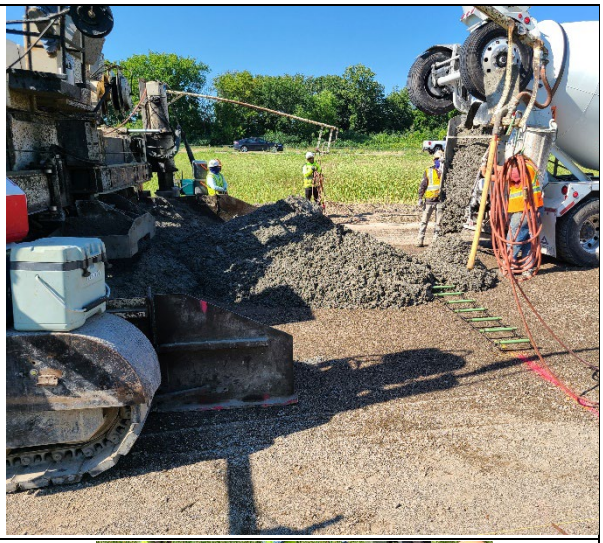
Cell 2217 Carbon Cure Control w/o CO2 Injection

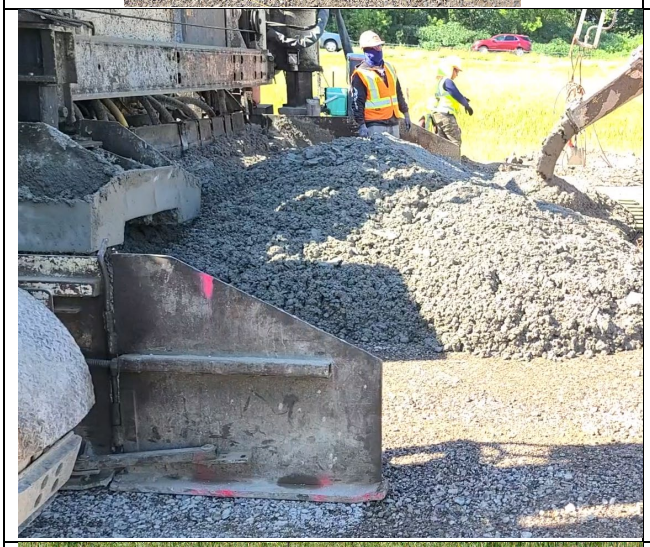
Cell 2218 Study Control





Cell 2219 Optimized Gradation

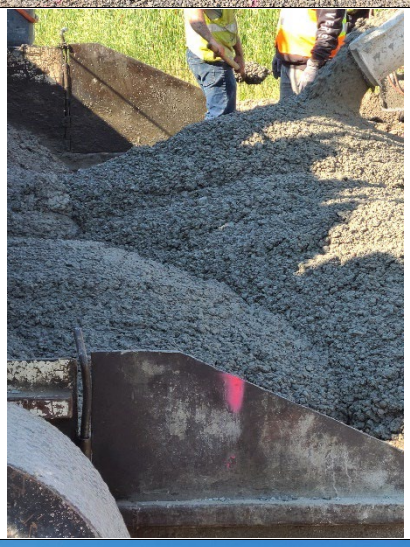




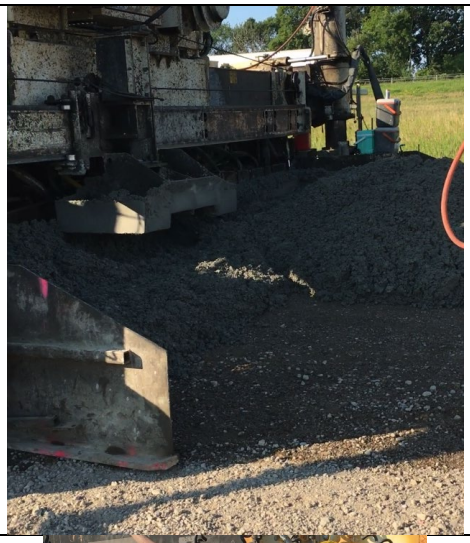
Cell 2220 Burgess Pigment

Cell 2221 3M

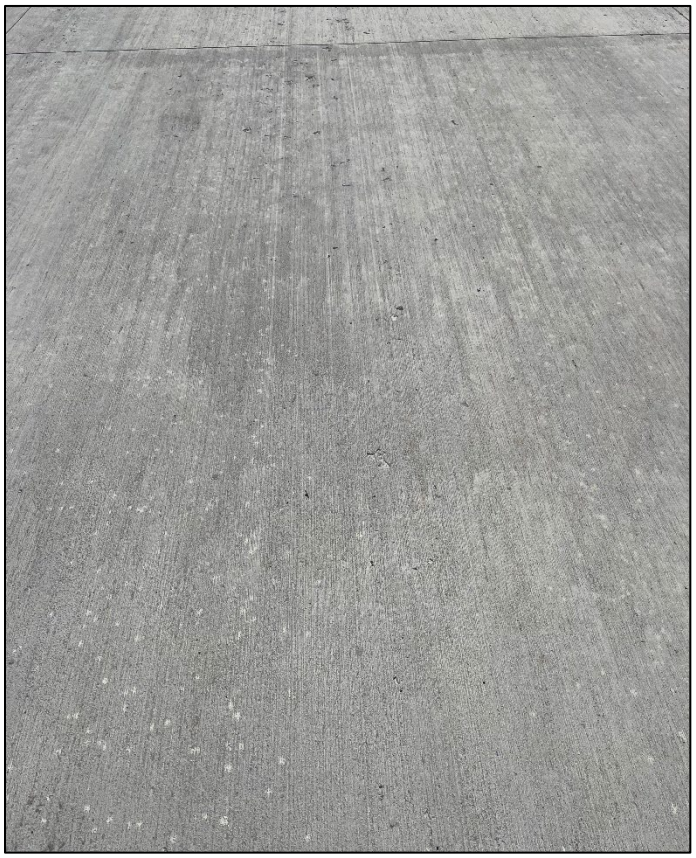





Cell 2222 Hess Pumice



Cell 2223 Continental Cement IL(20)



Cell 2224 Carbon Limit