CONSTRUCTION OF 2024 MNROAD TEST SECTIONS

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Introduction

As part of an ongoing effort to demonstrate the feasibility of using low-carbon cements for pavement construction, the Minnesota Department of Transportation (MnDOT) built eight test cells at its test facility on I-94 in 2024. This case study document describes the materials used, the work conducted (including by National Concrete Pavement Technology Center [CP Tech Center] staff), and the observations made regarding constructability and initial test data.

Project Information

Construction of the eight test sections took place during September 2024. Requirements for all of the sections were as follows:

- The materials had to be batched in a ready mix plant.
- Paving had to be conducted using a slipform paver.
- The mixtures had to be targeted to meet MnDOT performance requirements based on relevant sections from AASHTO R 101.

The MnDOT control mixture was based on the following parameters:

- Maximum water-to-cementitious materials (w/cm) ratio = 0.40
- Cement type = AASHTO M 595 Type IL
- Fly ash dosage = 30%
- Target air content = 7%

The mixtures placed in the different test sections (cells) are shown in Table 1.

PCiRoads constructed the test sections in September 2024 using a slipform paving machine. Ready mix trucks delivered concrete to the site. Each cell required about 20 truckloads of concrete.

Samples were collected three times during the paving of each cell by American Engineering Testing (AET), a commercial service. The AET team conducted the tests discussed below under Concrete Placement and reported them to the researchers.

Table 1. Test section mixtures

Cell	Mix Code	Mixture Description
2401	AG	Ash Grove LC3
2402	MC	Microspheres in control mixture
2403	KS	SCA mixture – Type IL + slag (24) + fly ash (20) + natural pozzolan (8)
2404	MO	Microspheres in reduced binder mixture
2405	SC	Control mixture – Type IL + fly ash (30)
2406	CC	C-Crete – slag cement + activator
2407	TC	Holcim ternary
2408	OZ	Ozinga 1157 (80) + Type IL

Members of the CP Tech Center team, including a student from the University of North Carolina at Charlotte, were present for the construction of all of the cells to provide support to the Federal Highway Administration (FHWA) Mobile Concrete Technology Center (MCTC) team, which was also tasked with collecting and testing samples.

Materials

Aggregates

The sources of the aggregates used in the mixtures are shown in Table 2.

Table 2. Aggregate properties

Aggregate Type	Label	Source	Specific Gravity	Water Absorption (%)
Coarse #1	¾ in.	Elk River	2.63	1.2
Coarse #2	#67	Elk River	2.69	1.3
Coarse #3	CIA	Elk River	2.67	1.5
Fine	Sand	—	2.67	0.9

Combined aggregate gradations for the mixtures as designed are shown in Figure 1.

Mixture Proportions

Table 3 is a summary of the mixture proportions used as an average of the data provided in the delivery tickets.

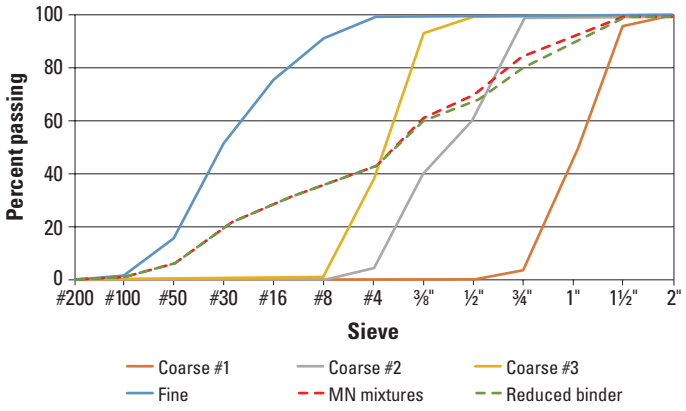

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Figure 1. Material and mixture gradations

Table 3. Concrete mixture proportions

Component	Units	2401 AG	2402 MC	2403 KS	2404 MO	2405 SC	2406 CC	2407 TC	2408 OZ
Cement	lb/yd³	570	402	432	360	400	700	285	130
Fly Ash	lb/yd³	0	268	108	240	170	0	171	0
Slag	lb/yd³	0	0	108	0	0	0	114	397
Rock 1	lb/yd³	453	449	743	626	457	381	457	437
Rock 2	lb/yd³	1187	1145	906	1042	1167	916	1166	1131
Rock 3	lb/yd³	211	239	279	251	244	205	244	250
Sand	lb/yd³	1160	1149	1160	1203	1171	1415	1170	1290
Water	lb/yd³	239	260	205	232	228	224	228	220
Water-Reducing Admixture (WRA)	oz/cwt	2.0	2.0	2.0	2.0	2.0	7.0	2.0	2.0
Air-Entraining Admixture (AEA)	oz/cwt	1.0	0.0	1.8	0.0	1.0	1.0	1.0	1.0
Microspheres	lb/yd³	—	5.0	—	5.0	—	—	—	—
w/cm	—	0.42	0.39	0.32	0.39	0.40	0.32	0.40	0.42
Binder	lb/yd³	570	670	648	600	570	700	456	527
Supplementary Cementitious Materials (SCM)	% mass	0%	40%	33%	40%	30%	0%	63%	75%

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Figure 2. Construction of Cell 2405

Concrete Placement

All eight cells were placed between September 9 and 12, 2024. In general, the placement of all cells was successful, although some mixtures needed field adjustments to the amount of water added. Construction of one of the cells is shown in Figure 2.

Three sets of samples were collected by the AET team to measure fresh properties at the site and to measure hardened properties in the laboratory.

The fresh properties included the following:

- ASTM C231, air content
- AASHTO TP 118, Super Air Meter (SAM)
- AASHTO T196, Rollameter
- ASTM C457, hardened air content
- ASTM C138, unit weight
- AASHTO T119, slump
- ASTM C1064, temperature
- AASHTO T396, Box

The hardened properties included the following:

- ASTM C39, compressive (set of two – 6 x 12) – laboratory curing, as-built
- ASTM C78, flexural (set of two) – laboratory curing, one day
- AASHTO T358, surface resistivity (1, 3, 7, 14, 28, 42, and 56 days)
- ASTM C1202, rapid chloride permeability (56, 91, and 120 days)
- ASTM C666, freeze-thaw

The results of additional testing conducted by MCTC staff have not yet been reported.

Field Concrete Test Results

Fresh concrete properties were monitored during placement and are summarized in Table 4.

Hardened concrete properties reported to date are shown in Table 5.

Closing

All of the mixtures met the required performance targets based on the data received to date.

Table 4. Fresh concrete properties

Mix	Cell	Date	Slump (in.)	Air (%)	SAM	U/W (lb/ft³)	Temp (°F)	Box Number	VKelly (in./√s)
AG	2401	Sept. 9	1.1	7.3	0.25	143.7	75	1.25	1.00
MC	2402	Sept. 9	4.2	3.4	—	153.7	73	2.13	0.66
KS	2403	Sept. 10	1.7	5.1	0.24	145.4	73	1.00	—
MO	2404	Sept. 10	2.2	4.9	—	154.7	74	1.50	0.85
SC	2405	Sept. 11	1.4	6.3	0.23	146.5	75	1.50	0.73
CC	2406	Sept. 11	1.7	3.7	0.13	148.7	84	2.00	0.56
TC	2407	Sept. 12	1.8	6.3	0.14	145.9	75	1.25	0.65
OZ	2408	Sept. 12	0.8	5.8	0.27	146.4	78	1.25	0.55

Table 5. Hardened concrete properties

Mix	Cell	Strength	Units	Age (Days)						
				1	3	7	14	28	42	56
AG	2401	Compression	psi	1710	2320	3060	3240	3480	3860	4070
		Flexural	psi	210	410	505	525	570	—	535
		Resistivity	kohm.cm	3.8	5.7	12.9	18.8	24.9	29.7	31.5
MC	2402	Compression	psi	2580	3380	4090	4610	5490	5870	6360
		Flexural	psi	400	460	560	680	690	—	790
		Resistivity	kohm.cm	6	6.9	9	13.8	25.6	36.1	42
KS	2403	Compression	psi	1390	2250	3410	3990	4350	4770	4940
		Flexural	psi	315	455	575	665	725	—	640
		Resistivity	kohm.cm	5.1	9	18.7	34.9	56.3	69.8	82.4
MO	2404	Compression	psi	2140	3180	3710	4520	5210	5860	6270
		Flexural	psi	275	490	510	590	695	—	775
		Resistivity	kohm.cm	6.1	8.4	10.7	15.2	26.9	35.1	45.3
SC	2405	Compression	psi	2450	3030	3590	3950	4500	4710	4940
		Flexural	psi	420	505	545	555	615	—	710
		Resistivity	kohm.cm	6.7	9.3	11.3	17.5	23.8	29.8	37.7
CC	2406	Compression	psi	3750	4210	4860	5230	5970	6120	6310
		Flexural	psi	635	625	680	680	760	—	805
		Resistivity	kohm.cm	31.5	27.3	34.2	40.2	46.1	58.9	66.4
TC	2407	Compression	psi	1650	2390	3180	3910	4620	4740	5060
		Flexural	psi	405	540	590	675	770	—	780
		Resistivity	kohm.cm	5.6	7.8	13.8	26.8	46.7	60.0	71.9
OZ	2408	Compression	psi	1050	2330	3270	3600	4050	4160	4280
		Flexural	psi	260	485	620	640	730	—	715
		Resistivity	kohm.cm	12.2	43.9	71.4	113.1	133.8	148.8	154.5

About the National Concrete Pavement Technology Center

The mission of the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University is to unite key transportation stakeholders around the central goal of developing and implementing innovative technology and best practices for sustainable concrete pavement construction and maintenance.