Laboratory Evaluation of Roller-Compacted Concrete

Final Report for MLR-86-6

September 1988

Highway Division

Iowa Department of Transportation

LABORATORY EVALUATION OF ROLLER-COMPACTED CONCRETE

Final Report
for
Project No. MLR-86-6

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ABSTRACT

Fine limestone aggregate is abundant in several areas of the state. The aggregate is a by-product from the production of concrete stone. Roller compacted concrete (RCC) is a portland cement concrete mixture that can be produced with small size aggregate. The objective of the research was to evaluate limestone screenings in RCC mixes.

Acceptable strength and freeze/thaw durability were obtained with 300 pounds of portland cement and 260 pounds of Class C fly ash. The amount of aggregate passing the number 200 sieve ranged from 4.6 to 11 percent. Field experience in Iowa indicates that the aggregate gradation is more critical to placeability and compactibility than laboratory strength and durability.

INTRODUCTION

Roller compacted concrete (RCC) is a zero slump portland cement concrete mixture. RCC has been used for several years in construction of dams and airport runways. Recently, interest has been expressed in Iowa for RCC for highway pavement. A laboratory evaluation was needed to determine what effects cement and fly ash content, moisture content and aggregate source would have on the strength and durability of RCC for pavement in Iowa.

OBJECTIVE

The objective of the study was to determine the factors that would lead to a strong, durable, economical RCC pavement using limestone screenings.

MATERIALS

The following materials were used in this study (aggregate gradations are in Appendix A):

Portland cement: Type I, standard laboratory blend of eight portland cements available in Iowa (AC6-350)

Fly ash: Ottumwa, Class C (ACF6-82) (Appendix B contains the analysis)

Limestone screenings: Montour, crushed limestone A86002 Class 3 durability (AAR6-350)

Lemley East #5, crushed limestone A04016 Class 2 durability (AAR6-448)

Garrison B, crushed limestone A06006 Class 2 durability (AAR7-19)

Weeping Water, crushed limestone ANE002 Class 3 durability (AAR7-33)

Fine aggregates: Bromley-Clemons A64504 (AAS6-275)
Oreapolis #8 ANE514 (AAS7-5)

TESTING PROCEDURE

Phase I of the study involved six mixes at various cement and fly ash levels and moisture levels. The cementitious material levels were selected to have an equal absolute volume of both fly ash and portland cement. Moisture levels were set at 1/2 percent below and 1 percent above optimum moisture content as determined by Standard Proctor (AASHTO T-99). The limestone screenings were chosen because of their abundance and relatively low cost. Screenings are a by-product from the production of concrete stone. The combined gradations are in the Appendix and shown in Figure 1.

All the strength and durability specimens for Phase I were compacted into 4-inch diameter by 4.584-inch high cylinders using standard proctor compactive efforts. Mixing was accomplished using a 1.75 cubic foot capacity pan mixer. The aggregates were added to the mixer in an oven dry condition. Table 1 contains the results of testing. The freeze/thaw was by ASTM C666, Method B. Because of the size of the specimens only visual evaluation of the condition was done.

The results of the freeze/thaw testing suggest that an RCC mix with a cementitious material factor lower than 557 pounds per cubic yard may be susceptible to freeze/thaw deterioration. The 28-day

FIGURE 1. COMBINED AGGREGATE GRADATIONS

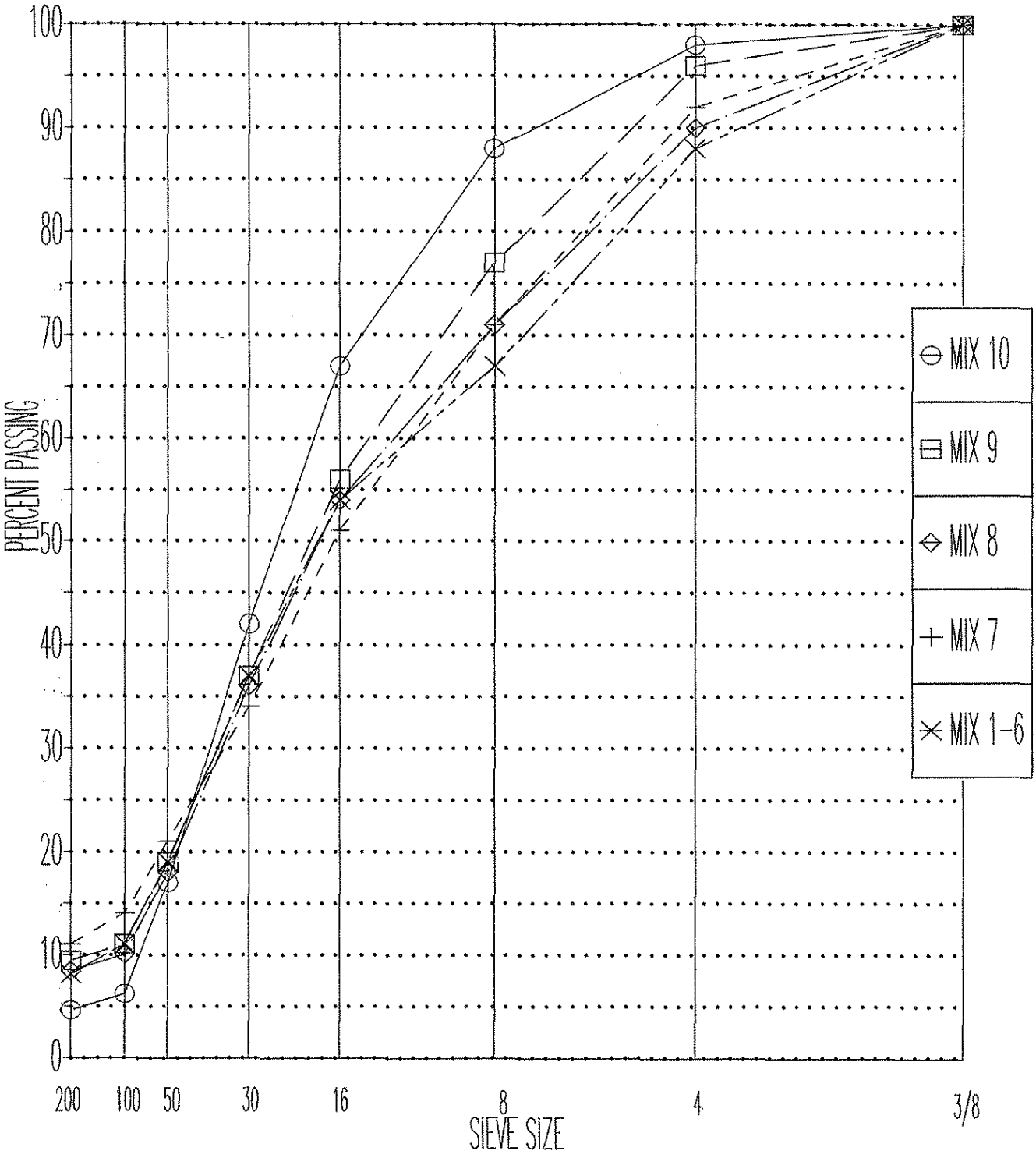

Table 1
Phase I Mix Results

MIX NO.	CEMENT LB/YD3	FLY ASH LB/YD3	OPT. MOISTURE % (LB/YD3)	WATER USED LB/YD3	W/C+FA*	DRY DENSITY LB/FT3	28-DAY COMPRESSIVE STRENGTH PSI	NUMBER OF FREEZE/THAW CYCLES TO VISUAL FAILURE
1	193	165	8.04 (293)	274	0.765	135.3	4430	179
2	193	165	8.04 (293)	323	0.902	134.3	3195	99
3	234	201	8.62 (314)	297	0.683	137.2	6365	215
4	234	201	8.62 (314)	329	0.756	133.8	4765	157
5	300	257	7.70 (283)	270	0.485	135.8	7550	313[a]
6	300	257	7.70 (283)	297	0.533	135.3	7870	313[a]

*Mixed with aggregates in an oven dried condition

a. No deterioration was observed on Mix 5 or 6

Table 2
Phase II Mix Results

MIX NO.	CEMENT LB/YD3	FLY ASH LB/YD3	COARSE AGGREGATE	FINE AGGREGATE	OPT. MOISTURE % (LB/YD3)	WATER USED LB/YD3	W/C+FA*	DRY DENSITY LB/FT3	28-DAY COMP STRENGTH PSI	DURABILITY
5	300	257	60% Montour	40% Bromley	7.70 (283)	270	0.485	135.8	7550	
7	304	261	75% Lemley	25% Bromley	8.03 (301)	301	0.533	137.0	6340	92
8	302	258	50% Garrison	50 Bromley	8.20 (307)	307	0.548	136.5	7520	94
9	307	267	60% Weeping Water	40% Oreapolis	7.70 (290)	290	0.505	139.5	6530	96
10	302	262	30% Weeping Water	70% Oreapolis	8.20 (303)	303	0.537	135.1	6460	96

compressive strength for both mixes 5 and 6 were comparable to average laboratory strengths for pc concrete mixes with 600 to 700 pounds of cement per cubic yard.

Phase II of the study involved four mixes using aggregates from locations where field projects were envisioned. The mixing and compaction procedures were the same as used in Phase I. Based on the results from mix 5 of Phase I, the decision was made to use a minimum 557 pound cementitious material factor at optimum moisture for the Phase II mixes.

Durability samples were made for each mix. The compaction procedure was 3, 1.33-inch lifts and 100 blows per lift with the Standard Proctor hammer to mold the 4-inch by 4-inch by 18-inch rectangular specimens. ASTM C666, Method B modified was used. The results of the Phase II testing are in Table 2. The strengths for all the mixes were above 6000 psi on the 28-day compressive strength. Durability factors were well above what would be expected for mixes with no entrained air structure.

DISCUSSION

Many different aggregate gradations have been used successfully for RCC mixes. This study has concentrated on the gradations normally available with limestone screenings in Iowa. All mixes produced with more than 300 pounds of cement and 255 pounds of fly ash per cubic yard tested satisfactory for both strength and freeze/thaw

durability. The percent of aggregate passing the number 200 sieve ranged from 4.6 to 11 percent.

CONCLUSIONS

The following conclusions can be made based on this study:

1. With the aggregates studied, about 300 pounds of cement and 260 pounds of fly ash per cubic yard of mix was needed to obtain satisfactory strength and durability.

2. Class 2 or better limestone screening of various gradations blended with concrete sand appear to be suitable for RCC mixes.

3. The freeze/thaw durability of the RCC mixes without air entraining was much better than what is normally obtained for regular concrete mixes without air entraining.

RECOMMENDATIONS

The following recommendations can be made:

1. The minimum cement and fly ash factor for RCC should be established at 300 pounds of cement and 260 pounds of Class C fly ash.

2. The aggregate gradation should be established to meet placeability and compactability demands for the project. Mix

designs should then be tested with that gradation to determine an optimum cement, fly ash and water content.

3. The aggregate quality should be limited to Class 2 durability or better for most field applications.

Appendix A

% Passing
Limestone Screenings

Sieve No.	Montour	Lemley East #5	Garrison 'B'	Weeping Water
3/8	100	100	100	100
#4	82	90	84	93
#8	56	67	58	63
#16	44	45	39	42
#30	32	31	28	30
#50	22	23	22	22
#100	17	18	18	18
#200	13	15	16	15

% Passing
Sand

Sieve No.	Bromley-Clemons	Oreapolis #8
3/8	100	
#4	96	100
#8	84	98
#16	70	78
#30	44	47
#50	15	15
#100	2.5	1.2
#200	0.7	0.1

Sieve	% Passing				
	MIX 1-6 60% Montour 40% Bromley-Clemons	MIX 7 75% Lemley East 25% Bromley-Clemons	MIX 8 50% Garrison 50% Bromley-Clemons	MIX 9 60% Weeping Water 40% Oreapolis	MIX 10 30% Weeping Water 70% Oreapolis
3/8	100	100	100	100	100
4	88	92	90	96	98
8	67	71	71	77	88
16	54	51	55	56	67
30	37	34	36	37	42
50	19	21	18	19	17
100	11	14	10	11	6.2
200	8.1	11	8.4	9.0	4.6

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Appendix B

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - MISCELLANEOUS MATERIALS
LAB LOCATION AMES

MATERIAL FLY ASH CLASS C LAB NO. ACF6-82

INTENDED USE PCC

COUNTY PROJ NO. DEPT. INFO.

DESIGN CONTRACT NO.

PRODUCER OTTUMWA GENERATING STATION CONTRACTOR
MARKETER: MIDWEST FLY ASH

SOURCE CHILLICOTHE, IA

UNIT OF MATERIAL MONTHLY MONITOR SAMPLE

SAMPLED BY STAN SMITH SENDER'S NO. 5SS6-44

SAMPLED 10-2-86 REC'D 10-6-86 REPORTED 11-12-86

CHEMICAL ANALYSIS - %

SIO2	35.15
AL2O3	21.41
FE2O3	5.31
SUBTOTAL	61.87
NA2O	2.23
K2O	0.42
ALKALI EQUIVALENT	2.51
AVAILABLE ALKALI	1.54
SO3	2.45
MOISTURE	0.06
LOSS ON 800 DEG. C. IGNITION	0.30
MGO	4.82
CAO	25.75

PHYSICAL TESTS ASTM C-311-85

SPECIFIC GRAVITY	2.67
POZZ. ACTIVITY	
7 DAY	109.0%
28 DAY	114.4%
WATER REQUIREMENT	84.2%
AUTOCLAVE	.05%
325 MESH	87.6% PSG.
SPEC. SURF.	12846 CM2/CM3
COMPRESSIVE STRENGTH	
FLY ASH & SAND:	
1 DAY	378 P.S.I.
7 DAY	463 P.S.I.

DISPOSITION: COMPLIES WITH ASTM 618 CLASS C

SIGNED: MAX I. SHEELER