Report No.CDOT-DTD-R-93-1

Dense Graded Concrete

Project FX(CX)083-1(53)

Ahmad Ardani
Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222

Final Report
February, 1993

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

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16. Abstract

This report describes and compares the performance of a dense graded mix against the traditional standard (gap-graded) mix. The dense graded mixture showed increased compressive strength by approximately ten percent over the gap graded mixture under the controlled laboratory condition. However, similarly prepared mixture in the field showed lower strength. It is the general consensus that the lower strength of the dense graded mix could have been caused by the higher slump (more water) and higher air. The results of the petrographic examination confirmed this phenomenon. Dirty intermitant aggregate may have caused lower strength for the dense mix.

Implementation

The concept of using dense graded mixture in place of the traditional gap graded mixture looks promising. However, there is still room for improvement in a fully implemented paving operation. More research is needed in this area to identify the proper proportioning of aggregate, air entraining admixture, and water cement ratios.

17. Key Words		18. Distribution Statement	
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Dense Graded Concrete Pavement

Project FX(CX)083-1(53)

Final Report

February 1993

Problem Statement:

Over the past few years much attention has been given to the use of dense-graded aggregates in PCC pavements. Although we are aware of their use by various paving industries, there are questions regarding the constructability, costs, and performance of dense-graded concrete which need to be addressed.

The general consensus is that intermediate sized aggregates and particle shape have a significant effect on the plastic workability and long-term performance of concrete pavement. The intermediate aggregates (aggregate sizes between 3/8 of an inch and number 8 sieve) will increase the density of the concrete mix by filling the space normally occupied by less dense concrete paste and water. Well-graded aggregates require less water and consequently lower w/c ratio. Reduction of the amount of water in the mix, reduces permeability, which in turn increases strength and long-term durability.

In general, the traditional gap graded materials can produce required compressive strength, but are generally not optimum to provide the needed workability for concrete pavements (1). Good particle size distribution also influences slump. A slump change of as much as 3 1/2 inches has been measured by providing sufficient intermediate particles in the mix. This helps allow the reduction in mix water, while maintaining a constant mix consistency (1).

Typical gap graded and dense graded mixtures are shown in Figure 1 and Figure 2.

Objective:

The primary objectives of this study were:

1- To demonstrate and compare the workability and strength of a dense-graded concrete mix against the traditional

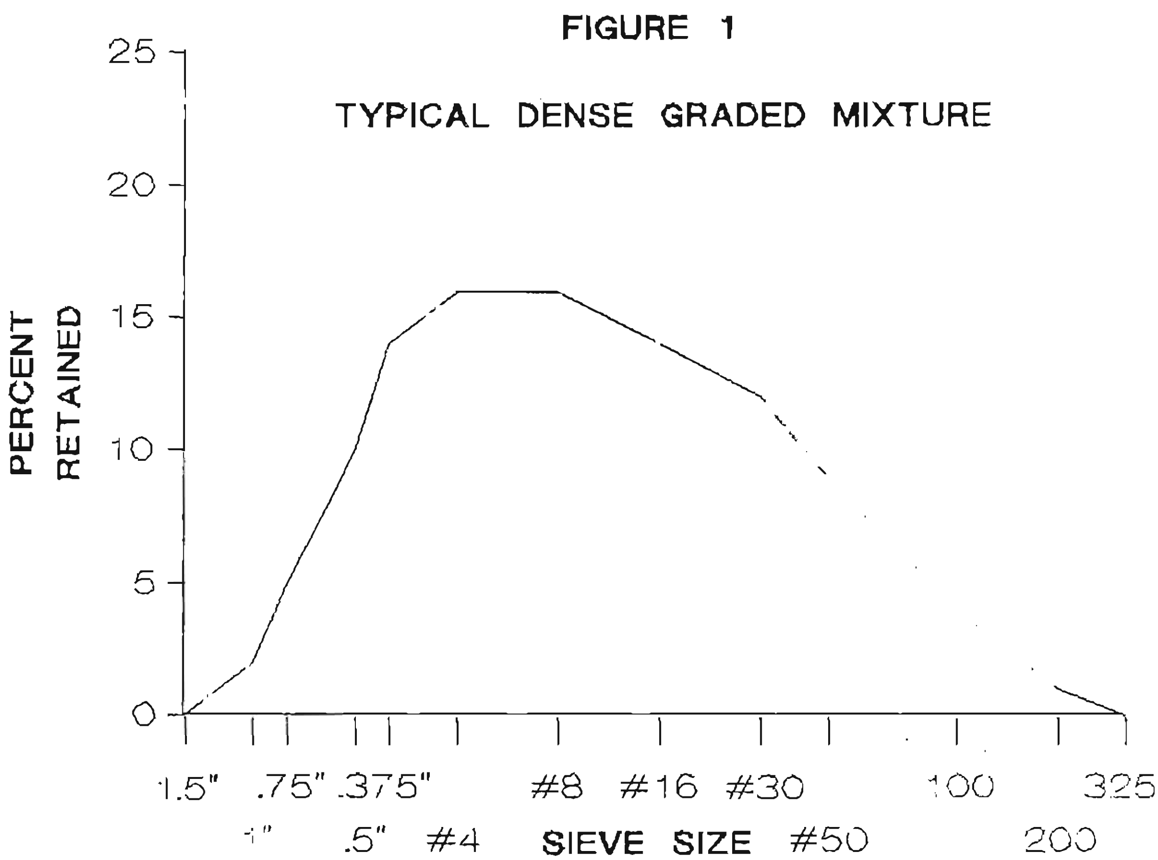


FIGURE 1
TYPICAL DENSE GRADED MIXTURE
PERCENT RETAINED
25
20
15
10
5
0
1.5"
1"
.75"
.5"
.375"
#4
#8
#16
#30
#50
100
200
325
SIEVE SIZE

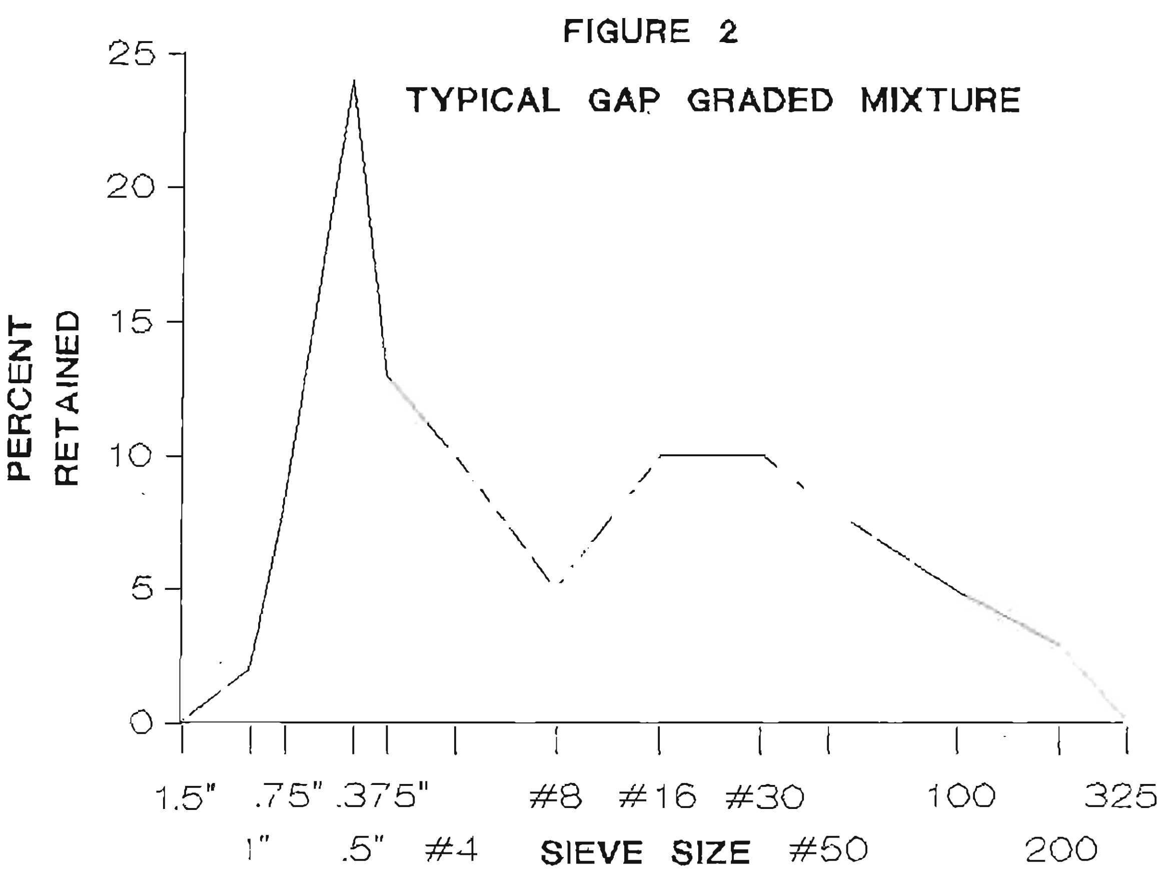


FIGURE 2
TYPICAL GAP GRADED MIXTURE
PERCENT RETAINED
25
20
15
10
5
0
1.5"
1"
.75"
.5"
.375"
#4
#8
#16
#30
#50
100
200
325
SIEVE SIZE

standard gap-graded mix on S.H 83 (Parker Road, Hilltop south).

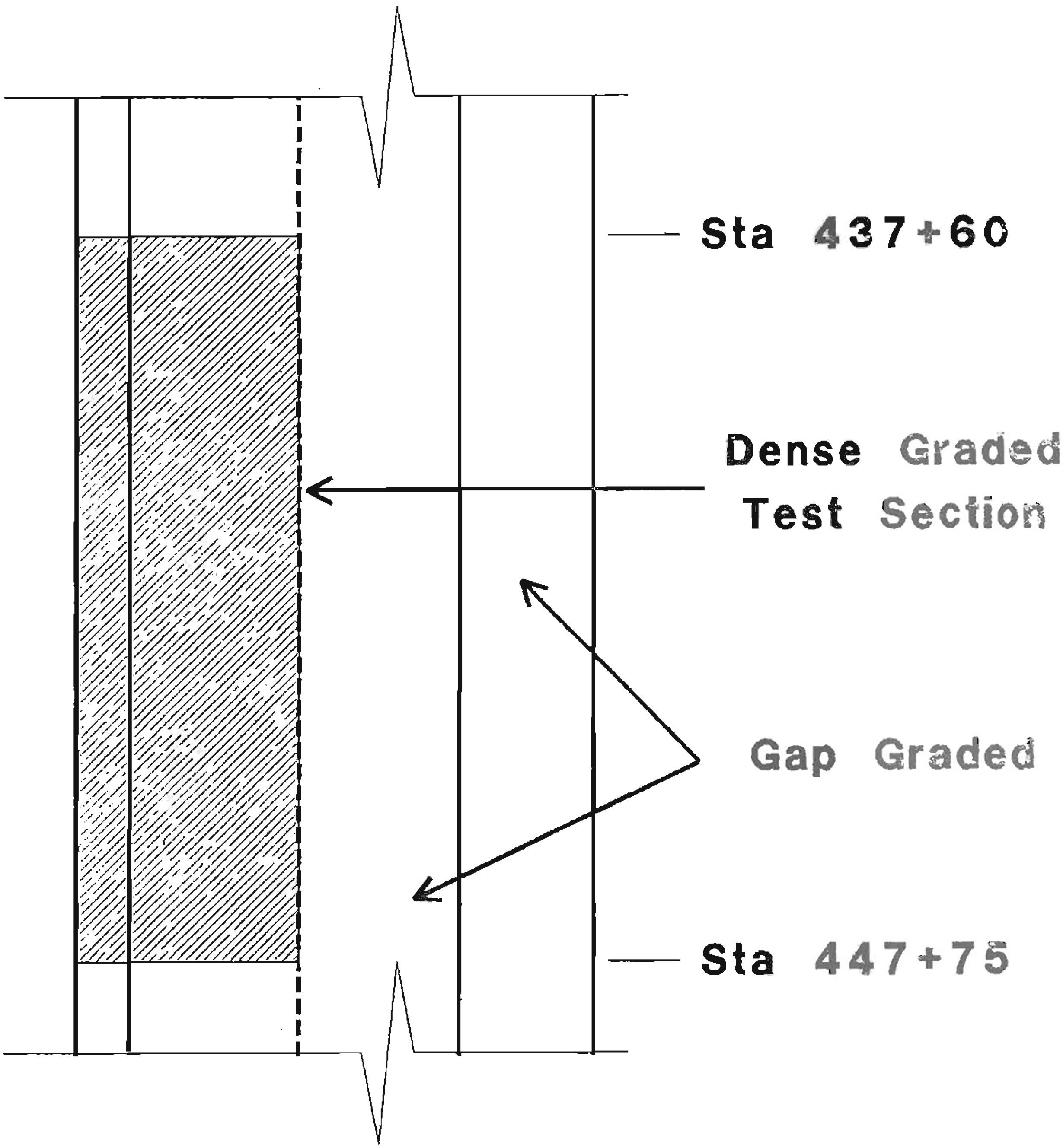
2- To incorporate the results into future pavement designs.

Dense Graded Concrete:

To investigate the effectiveness of a dense graded mix, a site was selected on S.H 83 South of the town of Parker. A test section was established in the northbound direction at station 437+60 - 447+75 with dense graded mixture in the passing lane. A control section (gap graded mix) was also established in the driving lane next to the test section with a standard mixture (Figure 3). The mix design for both mixtures are shown in Appendix A. The following criteria and materials were used in the mixes:

Slump (in)	1-1/2 - 2-1/2
Air Content (%)	4 to 8
Sand Content (%)	45% maximum
Cement	Ideal, Type I/II (455 Ibs/Cu. yards)
Fly Ash	Westen, Class C
Aggregate Sources	Centennial, Franktown, Cooley, Morrison

Figure 3
Project FX (CX)083-1(53)
SH 83 Northbound



The "Shilstone" computer program was used to optimize the particle size distribution for the dense graded mix. Based on the laboratory tests performed by the contractor, the 25 percent pea gravel addition increased the compressive strengths at equal cementitious materials content approximately 10 percent at ages 3 and 7 days.

Data Acquisition

During the construction cylinders were cast for both the test (dense graded) and the control (standard, gap graded) sections for 7, 14, and 28 days compressive strength. After the construction, cores were extracted from both sections for a complete petrographic examinations.

Petrographic examinations of the cores were performed in accordance with ASTM C 856-83, "Standard Practice for Petrographic Examination of Hardened Concrete" by CTL laboratories in Skoki Illinois. A longitudinal saw-cut through the core was lapped and examined at stereomicroscope magnifications up to 45X. To identify the aggregate and paste mineralogy and microstructure, a thin section approximately 20 micrometers (0.0008 in.) was examine using a polarize-light microscope at magnifications up to 250X. For complete results of the petrographic examination refer to Appendix B.

The paving operation was visually monitored to examine the constructibility of the dense graded mixture. Photograph 1 through 4 shows parts of paving operation for the dense graded mixture.

Data Analysis

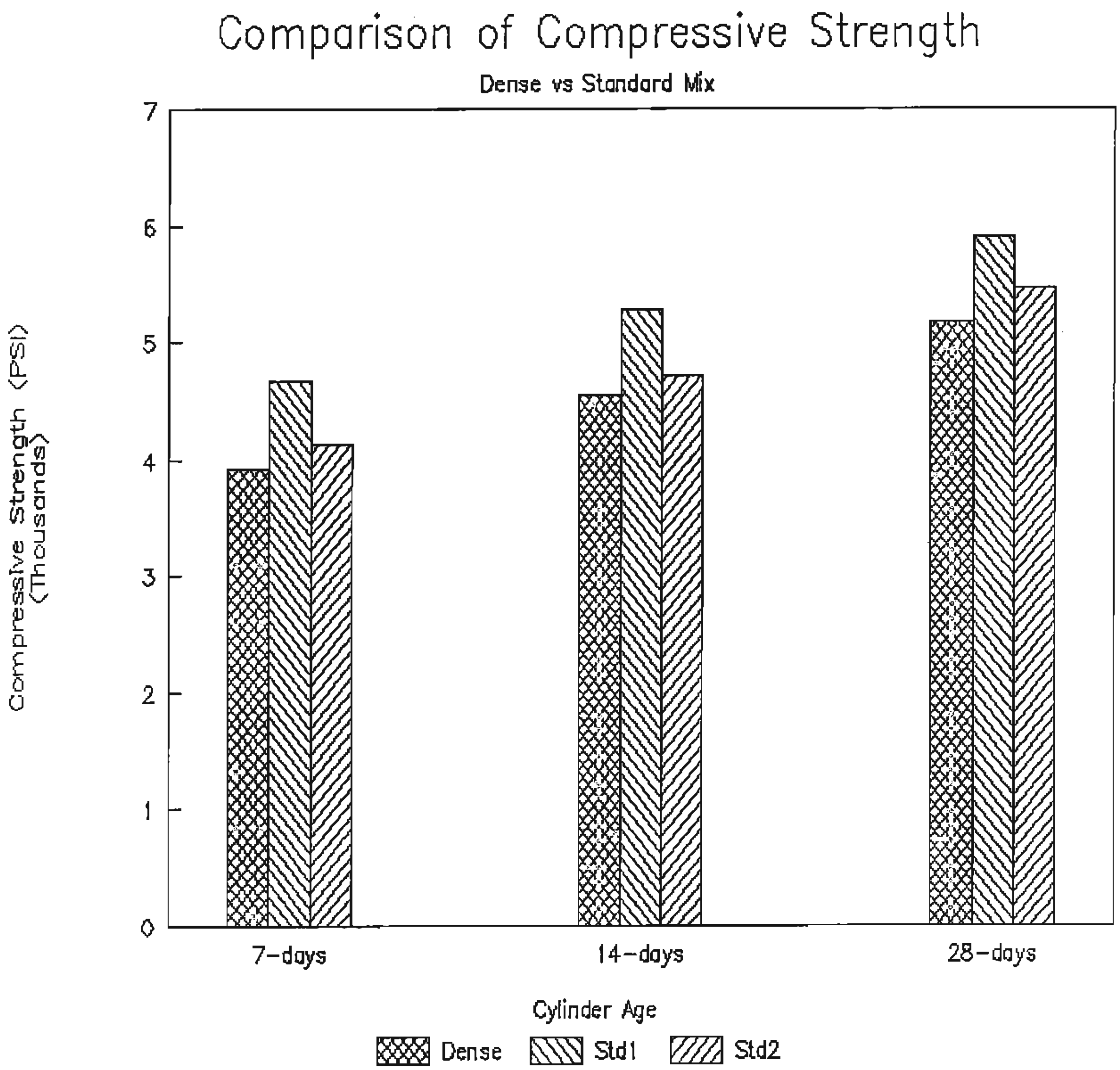
Visual inspection of the dense graded mixture during the paving operation revealed reduced workability (harder to finish). In an interview with the concrete finishers at the job site this phenomenon was confirmed. According to the concrete finishers the dense graded mixture required more work to finish than the standard mixture.

Figure 4 compares a dense graded mixture against two gap graded mixtures (standard). As it can be seen the 7, 14, and the 28 days compressive strength of the two gap graded mixtures are all higher than the compressive strength of the dense graded mixture. This contradicts the results obtained under the controlled laboratory conditions. Some of the reasons for this less than desirable performance by the dense graded mixture are listed below:

Photograph 1 & 2: A 16 foot inside lane was constructed using dense graded mixture

Photograph 3 & 4: The dense graded mixture required more finishing effort than the standard mixture

Figure 4



Comparison of Compressive Strength
Dense vs Standard Mix
Compressive Strength (PSI)
(Thousands)
7
6
5
4
3
2
1
0
7-days
14-days
28-days
Cylinder Age
Dense
Std1
Std2

- Based on the petrographic analysis performed by the CTL laboratories the W/C ratio of the dense graded mix was higher than the standard mix (0.45 vs. 0.375).

- The air content of the dense mix was also higher than the standard mix (6.5 vs. 4.0 percent).

- Dirty intermediate aggregate may have also caused lower strengths for the dense graded mix.

It should be noted that even though the compressive strength for the dense graded mix was lower than those of the gap graded mix, it still conformed to the requirements of the project specification. A recent distress survey of the pavement surface revealed no distresses for both the dense and the gap graded sections. These two sections have been in service approximately 18 months.

Conclusions and Recommendations

The concept of using dense graded mixture in place of the traditional gap graded mixture looks promising. However, there is still room for improvement in a fully implemented paving operation. More research is needed in this area to identify the proper porportioning of aggregate, air entraining admixture, and water cement ratios.

The dense graded mixture showed increased compressive strength by approximately 10 percent over the gap graded mixture under the controlled laboratory condition. However, similarly prepared mixture in the field showed lower strength. This suggests that water contents and air entraining admixture dosages may require appreciable adjustment in the field to maintain the desired fresh concrete properties.

A more stringent control on the aggregate cleanliness is recommended. Dirty intermediate aggregate may have played a role in lowering the compressive strength of the dense mix.

References

1- American Concrete Pavement Association (ACPA), "Fast Track Concrete Pavements", 1989.

Appendix A

RECEIVED MAY 24 1991

COMMERCIAL TESTING LABORATORIES

A DIVISION OF CTL/THOMPSON, INC.

CONCRETE TRIAL MIX STUDY
PARKER ROAD PROJECT

Prepared For:

Mr. Ralph Bell
Mr. Steve Peterson
Castle Rock Construction Company
P.O. Box 1148
Castle Rock, Colorado 80104

Job No. 5832

May 15, 1991

22 LIPAN STREET DENVER, COLORADO 80223 303 / 825-3207

TABLE OF CONTENTS

SCOPE

This report presents preliminary test results of a concrete trial mix study conducted in our laboratory facility. The primary purpose of this study was to attempt to qualify a mix using Centennial Franktown sand and Cooley Morrison No. 57 for use on the Parker Road project. This mix is to be a CDOH Class P per project specifications. The aggregate gradations were checked for conformance. A trial mixture was proportioned using sand and No. 57 in conformance with project specifications. For comparison purpose, an additional trial mixture was also proportioned with 25 percent Centennial pea gravel addition.

SUMMARY OF CONCLUSIONS

Based upon the preliminary results of this study, cement (cementitious materials) content is the controlling factor for meeting specification requirements. Both mixes in this study have attained at 7 days the minimum specification requirement for strength at age 28 days. The pea gravel addition in the comparison mix appears to have increased the early compressive strengths by 10 percent.

MATERIALS AND CRITERIA

The concrete trial mixes were proportioned and prepared in general conformance with ACI 211, project specifications, and your instructions. The following criteria and materials were used in the mixes:

Slump (in.):	1-1/2 to 2-1/2
Air Content (%):	4 to 8
Sand Content (%):	45% maximum
Cement:	Ideal, Type I/II (455 lbs/cu. yd.)
Fly Ash:	Western, Class C
Aggregate Sources:	Centennial, Franktown; Cooley, Morrison

22 LIPAN STREET DENVER, COLORADO 80223 303 / 825-3207

Aggregate Sizes:	C 33 Sand, Coarse No. 57 and Pea Gravel
Air-Entraining Admixture:	Prokrete AES
Water-Reducing Admixture:	Prokrete PDA50 @ 4 ozs/cwt

The mixes were proportioned to meet the requirements of the project specifications for minimum cementitious content (565 lbs/cu. yd.), air content (4 to 8 percent), and compressive strength (3000 psi f'c, 3750 psi in laboratory at age 28 days). The aggregates were tested to determine grading, absorption, and specific gravity, properties which affect trial mix proportions. The sand was tested for "sand equivalence". Results of these tests are presented in Table No. 1.

TRIAL MIX TEST RESULTS

On April 26, 1991, the trial mixes were batched using materials and criteria previously defined. Sand and water contents were adjusted to achieve the desired slump, and air-entraining admixture dosage was adjusted as necessary to achieve the specified air content. Tests on fresh concrete included air content (pressure method), slump, density, and temperature. Samples of concrete were cast for testing compressive strengths of concrete at ages 3, 7, and 28 days.

Tests indicate that the compressive strengths at age 7 days have met the minimum project specification requirement (3750 psi in laboratory at age 28 days). The 25 percent pea gravel addition increases the compressive strengths at equal cementitious materials content from 8 to 12 percent at ages 3 and 7 days. The pea gravel mix was proportioned to optimize aggregate particle size distribution, using the "Shilstone" computer program. Results of these tests and mix proportions used are presented in Table Nos. 2 and 3.

22 LIPAN STREET DENVER, COLORADO 80223 303 / 825-3207

LIMITATIONS

Concrete trial mix studies define the performance of a specific set of concrete-making ingredients in mixes prepared under controlled laboratory conditions. The performance of similarly prepared mixes in the field will vary from the trial mixes. Water contents and air-entraining admixture dosages may require appreciable adjustment in the field to maintain the desired fresh concrete properties. Water/cement ratios will change as the water requirement varies.

The performance of these mixes should be closely monitored in the field until a performance history is established. Based on surplus strength performance in the field, it may be possible to qualify a reduced cement content with caution, provided that air content and other requirements are maintained.

Changes in materials' properties will change the performance of concrete mixtures. Therefore, sources of materials should not be changed without further study. Moreover, significant changes in material fineness may appreciably change mix properties.

Very truly yours,

COMMERCIAL TESTING LABORATORIES

Hui Sheng Liang,
Project Engineer

Reviewed By:

Orville R. Werner II, P.E.,
Senior Engineer

HSL/ORW/jdd

Enclosures

TABLE NO. 1

PHYSICAL PROPERTIES OF AGGREGATES

Client: Castle Rock Construction, Inc.
Aggregate: Centennial Sand and Cooley Coarse No. 57

ASTM C 136, Sieve Analysis of Fine and Coarse Aggregates

Sieve Size	No. 57 Sample % Pass	ASTM C 33 #57 Specs. % Pass	Sand Sample % Pass	ASTM C 33 Sand Specs. % Pass
1-1/2"	100	100		
1"	98	95-100		
3/4"	81	-		
1/2"	38	25-60		
3/8"	20	-		100
No. 4	2	0-10	100	95-100
No. 8	1	0-5	90	80-100
No. 16			67	50-85
No. 30			40	25-60
No. 50			18	10-30
No. 100			6	2-10
ASTM C 117, Material Finer than No. Sieve (%):	0.9	1.0 Max.	1.9	3.0 Max.
ASTM C 127, Specific Gravity:	2.69		2.56	
ASTM C 128, Absorption (%):	0.9		1.4	
ASTM D 2419, Sand Equivalent:			86	80 Min.*

*CDOH specification requirement

CTL Job No.: 5832
Date: May 15, 1991

TABLE NO. 2

CONCRETE TRIAL MIX RESULTS
(Mix Made April 26, 1991)

Client: Castle Rock Construction, Inc.
Aggregates: Centennial Sand, Cooley Coarse #57
Cement: Ideal, Type I/II
Fly Ash: Western, Class C
AEA: Prokrete, AES
WRA: Prokrete, PDA50 @ 4 oz/cwt

CONCRETE MIX PROPORTIONS
(per cubic yard)

Ingredient	Z-1604	Job Specification
Cement, lbs.	455	455
Fly Ash, lbs.	110	110
AEA, ozs.	4.3	-
WRA, ozs.	22.6	-
Sand, lbs.	1305	1400 (45% Max.)
Coarse #57, lbs.	1800	-
Water, lbs/gals.	235/28.2	-

MIX PERFORMANCE

Property		
Unit Wt., pcf	142.4	-
Slump (in.)	2	-
Air Content, %	6.2	4-8
Water/Cement + Fly Ash Ratio	0.42	-
Temperature °F	67	-
Average Compressive Strength, psi		
3 days:	2760	-
7 days:	4220	-
28 days:	N/A	3000*

*CDOH specifications require an additional 750 psi in the laboratory

CTL Job No.: 5832
Date: May 15, 1991

TABLE NO. 3

CONCRETE TRIAL MIX RESULTS
(Mix Made April 26, 1991)

Client: Castle Rock Construction, Inc.
Aggregates: Centennial Sand, and No. 8, Cooley, Coarse #57
Cement: Ideal, Type I/II
Fly Ash: Western, Class C
AEA: Prokrete, AES
WRA: Prokrete, PDA50 @ 4 oz/cwt

CONCRETE MIX PROPORTIONS
(per cubic yard)

Ingredient	Z-1605	Job Specification
Cement, lbs.	455	455
Fly Ash, lbs.	110	110
AEA, ozs.	4.3	-
WRA, ozs.	22.6	-
Sand, lbs.	1055	1390 (45% Max.)
Pea Gravel, lbs.	780	-
Coarse #57, lbs.	1250	-
Water, lbs/gals.	235/28.2	-

MIX PERFORMANCE

Property		
Unit Wt., pcf	142.8	-
Slump (in.)	2-1/4	-
Air Content, %	5.8	4-8
Water/Cement + Fly Ash Ratio	0.42	-
Temperature °F	68	-
Average Compressive Strength, psi		
3 days:	3085	-
7 days:	4575	-
28 days:	N/A	3000*

*CDOH specifications require an additional 750 psi in the laboratory

CTL Job No.: 5832
Date: May 15, 1991

CONTRACTOR'S MIX DESIGN
REVIEW SHEET

Field Sheet No. ____________

CDOH # 91087
Project No. FC(CX) 083-1(53)
Item 412
Location Hilltop - South 2 mi
Class P
District 1
Specified Field Strength 3000 psi
Contractor Castle Rock Constr.
Required Lab Strength 3750 psi
Concrete Supplier Castle Rock Constr.

CONCRETE MIX PROPORTIONS (1Yd^3 SSD batch weights)

Cement	455 lb	Supplier	Ideal	Type	I/II LA
Flyash	110 lb	Supplier	Western	Class	C
Coarse	1800 lb	Pit	Cooley - Morrison		
Intermed	lb	Pit			
Sand	1305 lb	Pit	Centennial, Franktown		
AEA	AES oz	Manuf./Type	Procrete		
WRA	PDA50 oz	Manuf./Type	Procrete		
Water	235 lb				

PHYSICAL PROPERTIES OF TRIAL BATCH

Date 4-26-91
Slump 2"
Air Content 6.2%
Unit Weight 142.4
Water/Cement Ratio .42
Yield 27.4

COMPRESSIVE STRENGTH TEST RESULTS, PSI

7 - day 4220 14 - day ______ 28 - day ______

AGGREGATE TEST RESULTS Coarse, Intermediate, Fines

	Coarse: (Date)	Intermediate: (Date)		Fines: (Date)
Gradation	✓		Gradation/FM	✓ ✓ 2.79
Specific Gravities /Absorption	✓		Specific Gravities /Absorption	✓
LA Abrasion	✓ 28.3/26.2		Sand Equivalent	86

COMMENTS: The requirements of subsection 601.05(a) have been met with the following exceptions -
LA Abrasion on coarse aggregate
Fineness Modulus on fine aggregate

The requirements of subsection 601.05(a) have been met - June 24, 1991

Reviewed by: S. Kaye Stephenson
Date: June 4, 1991 / June 24, 1991

CONTRACTOR'S MIX DESIGN
REVIEW SHEET

CDOH # 91088
Item 412
Class PG
Specified Field Strength 3000 psi
Required Lab Strength 3750 psi

Field Sheet No.
Project No. FC(CX) 083-1(53)
Location Hilltop - South 2mi
District 1
Contractor Castle Rock Constr
Concrete Supplier Castle Rock Constr.

CONCRETE MIX PROPORTIONS (1Yd^3 SSD batch weights)

Cement 455 lb — Supplier Ideal — Type I/II LA
Flyash 110 lb — Supplier Western — Class C
Coarse 1250 lb — Pit Cooley - Morrison
~~Intermed~~ Squeegee 780 lb — Pit Centennial, Franktown
Sand 1055 lb — Pit Centennial, Franktown
AEA AE5 oz — Manuf./Type Procrete
WRA PDA50 oz — Manuf./Type Procrete
Water 235 lb

PHYSICAL PROPERTIES OF TRIAL BATCH

Date 4-26-91
Slump 2 1/4"
Air Content 5.8%
Unit Weight 142.8
Water/Cement Ratio .42
Yield 27.2

COMPRESSIVE STRENGTH TEST RESULTS, PSI

7 - day 4575 14 - day 28 - day

AGGREGATE TEST RESULTS Coarse, Intermediate, Fines

Coarse: May 15-91 (Date) — Intermediate: (Date) — Fines: May 15-91 (Date)

Gradation — Gradation/(FM) 2.79
Specific Gravities /Absorption — Specific Gravities /Absorption
LA Abrasion 28.3/26.2 — Sand Equivalent

COMMENTS: The requirements of Subsection 601.05(a) have been met with the following exceptions -
(1) LA Abrasion on coarse aggregate
(2) Fineness Modulus on fine aggregate
6-24-91 [initials]

Reviewed by: S. Kaye Stephenson Date: June 4, 1991

Project: FC (CX) 083-1(53)
Location: Hilltop - South 2 mi
Mix # 91087 - 91088

CONTRACTOR MIX REVIEW

The purpose of the Contractors Mix Design Review is to verify compliance with the end result concrete specification. The concrete mix proportions, physical properties of the trial mix, compressive strength test results, and aggregate test data will be reviewed.

The mix proportions must meet or exceed the minimum cement content and specified air content range. Bridge deck concrete shall have a maximum water/cement ratio of 0.44. The trial mix when tested at 28 days must produce 125% of the required field compressive strength.

Current aggregate tests of the coarse and fine aggregate shall be furnished as a part of the trial mix. The test data shall demonstrate compliance with the requirements of subsection 703.01 and 703.02. The nominal maximum size of the coarse aggregate shall comply with the specification requirements.

Return of the review sheet shall not constitute approval or acceptance of the concrete mix. The review process is to provide documentation for field personnel to determine project specification compliance.

Acceptance of the concrete shall be based solely on the air content and 28 day strength. Water cement ratio checks should be made when concrete is for bridge decks. All adjustments necessary to provide a mix meeting these specifications shall be the responsibility of the contractor.

A CDOH number has been assigned to the reviewed mix and is to be used on the DOH Form 82 in the space marked Mix Number.

cc: District Materials Engineer
Project Engineer
Documentation Unit File

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS

DATE TRANSMITTED : 01/02/80

PROJECT :FC(CX) 083-1(53)
LOCATION :HILLTOP - SOUTH
DISTRICT :100
FIELD SHEET: 58715
SUPPLIER :CRC

R E P O R T   O F   C O N C R E T E   T E S T S

ITEM NO :412
CONCRETE CLASS:P
DATE MOLDED :07/08/91
SLUMP : 1.25   AIR : 5.
CYLINDER SET NUMBER :01

PLACED AT :352+25
PORTION :NB 30' PASS
UNIT WEIGHT: 144.4

SPECIMEN NUMBER	DATE TESTED	AGE (DAYS)	COMPRESSIVE STRENGTH (PSI)
1	07/15/91	7	4670
2	07/15/91	7	4560
3	07/15/91	7	4660
4	07/22/91	14	5270
5	07/22/91	14	4840
6	07/22/91	14	5290
7	08/05/91	28	5800
8	08/05/91	28	5900
9	08/05/91	28	5910

REMARKS : CYLINDERS TESTED IN ACCORDANCE WITH AASHTO T-22 AS MODIFIED BY CP-66.
CYLINDERS MADE FOR RESEARCH, (VIBRATOR USED)

DISTRICT MATERIALS ENGINEER

CC: DISTRICT CONST ENGINEER
DISTRICT MATLS ENGINEER
RESIDENT ENGINEER (2)
CONTRACTOR (2) C/O RE
FILES

CDOH FORM #192
REVISED 3/89

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS

DATE TRANSMITTED : 07/26/91

PROJECT :FC(CX) 083-1(53)
LOCATION :HILLTOP - SOUTH
DISTRICT :100
FIELD SHEET: 58709
SUPPLIER :CASTLEROCK

REPORT OF CONCRETE TESTS

ITEM NO :412
CONCRETE CLASS:P
DATE MOLDED :06/28/91
SLUMP : 1.5 AIR : 5.5
CYLINDER SET NUMBER :01

PLACED AT :438+80
PORTION :NB 30 FT. PASS
UNIT WEIGHT: 144.8

SPECIMEN NUMBER	DATE TESTED	AGE (DAYS)	COMPRESSIVE STRENGTH (PSI)
1	07/05/91	7	4570
2	07/05/91	7	4140
3	07/05/91	7	4130
4	07/12/91	14	4940
5	07/12/91	14	4770
6	07/12/91	14	4660
7	07/26/91	28	4980
8	07/26/91	28	5530
9	07/26/91	28	5380

REMARKS : CYLINDERS TESTED IN ACCORDANCE WITH AASHTO T-22 AS MODIFIED BY CP-66.
CYLINDERS MADE FOR RESEARCH.

DISTRICT MATERIALS ENGINEER

CC: DISTRICT CONST ENGINEER
DISTRICT MATLS ENGINEER
RESIDENT ENGINEER (2)
CONTRACTOR (2) C/O RE
FILES

CDOH FORM #192
REVISED 3/89

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS

DATE TRANSMITTED : 01/01/80

PROJECT :FC(CX) 083-1(153)
LOCATION :HILLTOP - SOUTH
DISTRICT :100
FIELD SHEET: 58719
SUPPLIER :CRC

REPORT OF CONCRETE TESTS

ITEM NO :412
CONCRETE CLASS:P
DATE MOLDED :07/11/91
SLUMP : 1.75 AIR : 6.8
CYLINDER SET NUMBER :01

PLACED AT :446+30
PORTION :NB 16' PASS
UNIT WEIGHT: 146.

SPECIMEN NUMBER	DATE TESTED	AGE (DAYS)	COMPRESSIVE STRENGTH (PSI)
1X	07/18/91	7	3950
2X	07/18/91	7	3710
3X	07/18/91	7	3900
4X	07/25/91	14	4560
5X	07/25/91	14	4740
6X	07/25/91	14	4540
7X	08/08/91	28	5220
8X	08/08/91	28	5120
9X	08/08/91	28	4600

REMARKS : CYLINDERS TESTED IN ACCORDANCE WITH AASHTO T-22 AS MODIFIED BY CP-66.
CYLINDERS MADE FOR RESEARCH (VIBRATOR USED)

DISTRICT MATERIALS ENGINEER

CC: DISTRICT CONST ENGINEER
DISTRICT MATLS ENGINEER
RESIDENT ENGINEER (2)
CONTRACTOR (2) C/O RE
FILES

CDOH FORM #192
REVISED 3/89

Appendix B

Report to
STATE OF COLORADO DEPARTMENT OF HIGHWAYS

PETROGRAPHIC EXAMINATION OF TWO CONCRETE CORES TAKEN FROM PROJECT NO. FX(CX)083-1(53) AT HILLTOP-SOUTH 2 MILES, COLORADO DEPARTMENT OF HIGHWAYS

September 1991

CTL
Construction Technology Laboratories, Inc.
5420 Old Orchard Road, Skokie, Illinois 60077-1030

CTL
5420 Old Orchard Road, Skokie, Illinois 60077-1030
Phone: 708/965-7500 Fax: 708/965-6541

PETROGRAPHIC SERVICES REPORT

CTL Project No.: 152034 *Date:* September 18, 1991

Re: Petrographic Examination of Two Concrete Cores Taken from Project No. FX(CX)083-1(53) at Hilltop-South 2 Miles,Colorado Department of Highways

Two concrete cores labeled Core Nos. 1 (447+50)- and 2 (447+00) Proj. No. FX(CX)083-1(53) were received August 16, 1991 from Mr. Ahmad Ardani, Concrete and Special Studies Unit of the Department of Highways, State of Colorado.

Mr. Ardani reported that the cores were taken from a bridge deck of the above-referenced project. He requested full petrographic examination to evaluate their overall quality.

FINDINGS AND CONCLUSIONS

The following findings and conclusions are based on the result of the petrographic examination :

A. Both concrete core samples contain coarse aggregate of crushed stone consisting mainly of granite, quartzites (ortho and meta), metasedimentary rocks (sandstone and shale), chert and other siliceous rocks, and fine aggregate of natural sand.

1. The concrete in Core No. 1 is made of 1/2-inch crushed stone and 3/8-inch pea gravel that appears well graded and uniformly distributed.

2. The concrete in Core No. 2 is made of 1/2-inch crushed stone and appears gap graded (lacking 3/8-inch size) and uniformly distributed.

B. The paste microstructural characteristics of the two concrete core samples are summarized as follows:

Descriptive Criteria	Core Identification	
	Core No. 1	Core No. 2
a Paste Microstructure	a. No significant cracks observed. Some irregular voids up to 0.4 in. in diameter. Some randomly oriented, insignificant microcracks in the paste.	a. No significant cracks observed. Some irregular voids up to 0.3 in. in diameter. Some randomly oriented, insignificant microcracks in the paste.
b. Paste Hardness	b. Moderately hard.	b. Moderately hard to hard.
c. Paste/Aggregate Bond	c. Moderately strong.	c. Moderately strong.
d. Estimated Air Content	d. 5-8%, based on the occurrence of small spherical voids; in clusters, coalesce and nonuniformly distributed.	d. 3-5%, based on the occurrence of small spherical voids; in clusters, coalesce and nonuniformly
e. Estimated Water-to-Cementitious Ratio	e. Moderate (0.40 to 0.50).	e. Moderately low to moderate (0.35 to 0.40).

C. Although the concrete cores contain coarse aggregate having mineralogical composition that is prone to the expansive alkali-aggregate reaction (i.e. chert, metaquartzite, etc.), no alkali-silica gel or reaction rims were observed.

D. Additional details of the petrographic examinations are presented in the attached forms.

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RECOMMENDATION

To identify and confirm alkali-silica reactions (ASR) in the two concrete cores, it is recommended that a systematic "gel fluorescence test" be undertaken.*

* K. Natesaiyer, D. Stark, and K. C. Hover: "Gel Fluorescence Reveals Reactions Product Traces," Concrete International, January 1991, pp. 25-28.

METHODS OF TEST

Petrographic examinations of the cores were performed in accordance with ASTM C 856-83 (reapproved 1988), "Standard Practice for Petrographic Examination of Hardened Concrete." A longitudinal saw-cut surface through the core was lapped and examined at stereomicroscope magnifications up to 45X.

For thin section examinations, rectangular blocks were cut near the top surface of cores, placed on a glass microscope slide with epoxy resin, and reduced to a thickness of approximately 20 micrometers (0.0008 in.). The thin section was examined using a polarized-light microscope at magnifications up to 250X to determine aggregate and paste mineralogy and microstructure.

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Senior Petrographer
Supervisor, Petrographic Services

AGN/cjd

Attachments

FIG. 1 TOP VIEWS OF CORE NO. 1 (447+50) AND CORE NO. 2 (447+00).

FIG. 2 SIDE VIEWS OF CORE NO. 1 AND CORE NO. 2, AS RECEIVED FOR TESTING.

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FIG. 3 LONGITUDINALLY SAWED AND LAPPED SLICE OF CORE NO. 1 SHOWING 1/2 INCH CRUSHED STONE AND 3/8-INCH PEA GRAVEL COARSE AGGREGATES. CORE WAS SAWCUT NEAR BOTTOM SURFACE TO FIT INTO LAPPING MACHINE.

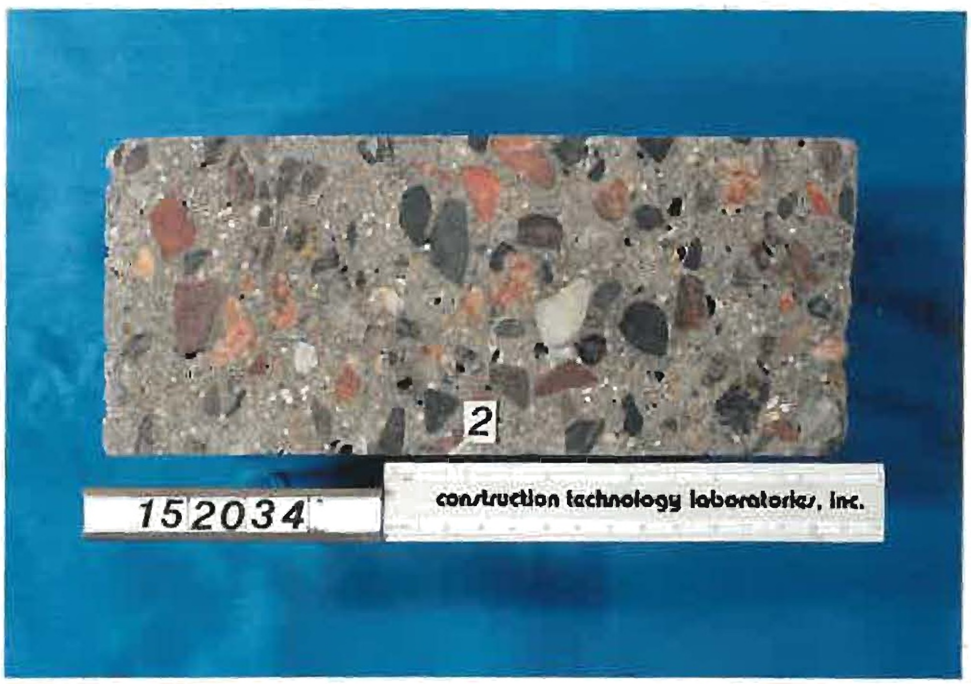

FIG. 4 LONGITUDINALLY SAWED AND LAPPED SLICE OF CORE NO. 2 SHOWING GAP GRADED COARSE AGGREGATE (LACKING 3/8-IN.-SIZE).

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PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 152034
CLIENT: Colorado Dept. of Highways
STRUCTURE: Bridge Deck
LOCATION: Hilltop - South 2 miles

DATE: September 18, 1991
PROBLEM: Quality Evaluation
EXAMINED: A. G. Nisperos

SAMPLE:

Identification: Core #1 - FC(CX)083-1(53), 447+50, PASS. LN. (RETEST).

Dimensions: Diameter = 3.7 in.: Length = 8.4 in.

Top Surface: Broomed-surface is tined , containing up to 0.10 in.-deep, and 0.12-in.-wide grooves approximately 0.70 in. apart.

Bottom Surface: Irregular surface with exposed fine and coarse aggregate particles as part of subbase.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.4 in. diameter scattered over body of core.

Reinforcement: None observed.

AGGREGATES (A)

Coarse: Crushed stone consisting mainly of granite ,quartzites (ortho and meta), metasediments (sandstone and shale), chert, and other siliceous rocks.

Fine: Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments

Gradation & Top Size: Well-graded, 1/2 inch and 3/8-inch size (pea gravel); with top size of 1.0 in.; predominantly 0.3 to 0.4 in.

Shape & Distribution: CA is subangular to angular, equant to elongate-shaped; FA is subangular to subrounded and spherical; Uniform distribution.

PASTE

Color: Medium-light gray.

Hardness: Moderately hard.

Luster: Subvitreous.

Calcium Hydroxide*: (5 - 10%).

Unhydrated Portland Cement Clinker Particles (UPC's)*: Residual cement particles are present in moderate amount (5-10%).

Depth of Carbonation: 0.1 in. below exposed surface.

Air Content: Estimated to be 5-8%, based on the occurrence of small spherical voids, some occurs in clusters, coalesce and nonuniformly distributed.

Fly Ash*: 10 - 15%, relatively carbon-rich.

Paste-Aggregate Bond: Moderately strong.

Secondary Deposits: Small patches of ettringite in air-voids.

Microcracking: Some randomly oriented, insignificant microcracks in the paste.

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*percent by volume of paste

ESTIMATED WATER-CEMENTITIOUS RATIO: MODERATE (0.4O - 0.50).

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PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 152034
CLIENT: Colorado Dept. of Highways
STRUCTURE: Bridge Deck
LOCATION: Hilltop - South 2 miles

DATE: September 18, 1991
PROBLEM: Quality Evaluation
EXAMINED: A. G. Nisperos

SAMPLE:

Identification: Core #2 - FC(CX)083-1(53),447+00-8-7/8."

Dimensions: Diameter = 3.7 in.: Length = 8.8 in.

Top Surface: Broomed-surface is tined , containing up to 0.10 in.-deep, and 0.15-in.-wide grooves approximately 0.70 in. apart.

Bottom Surface: Irregular surface with exposed fine and coarse aggregate particles as part of subbase.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.3 in. diameter scattered over body of core.

Reinforcement: None observed.

AGGREGATES (A)

Coarse: Crushed stone consisting mainly of granite, quartzites (ortho and meta), metasediments (sandstone and shale), chert, and other siliceous rocks.

Fine: Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments

Gradation & Top Size: Gap graded (lacking 3/8-inch to #4); predominantly 1/2-in. size.

Shape & Distribution: CA is subangular to angular, equant to elongate-shaped; FA is subangular to subrounded and spherical; Uniform distribution.

PASTE

Color: Medium-light gray.

Hardness: Moderately hard to hard.

Luster: Subvitreous.

Calcium Hydroxide*: (3 - 8%).

Unhydrated Portland Cement Clinker Particles (UPC's)*: (8-15%).

Depth of Carbonation: 0.1 in. below exposed surface.

Air Content: Estimated to be 3-6%, based on the occurrence of small spherical voids, some occurs in clusters, coalesce, and nonuniformly distributed.

Fly Ash*: 10 - 15%, relatively carbon-rich.

Paste-Aggregate Bond: Moderately strong to strong.

Secondary Deposits: Occurrence of calcium hydroxide and ettringite in air-voids.

Microcracking: Some randomly oriented, insignificant microcracks in the paste.

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*percent by volume of paste

ESTIMATED WATER-CEMENTITIOUS RATIO: Moderately low to moderate (0.35 - 0.45).