

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.			
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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

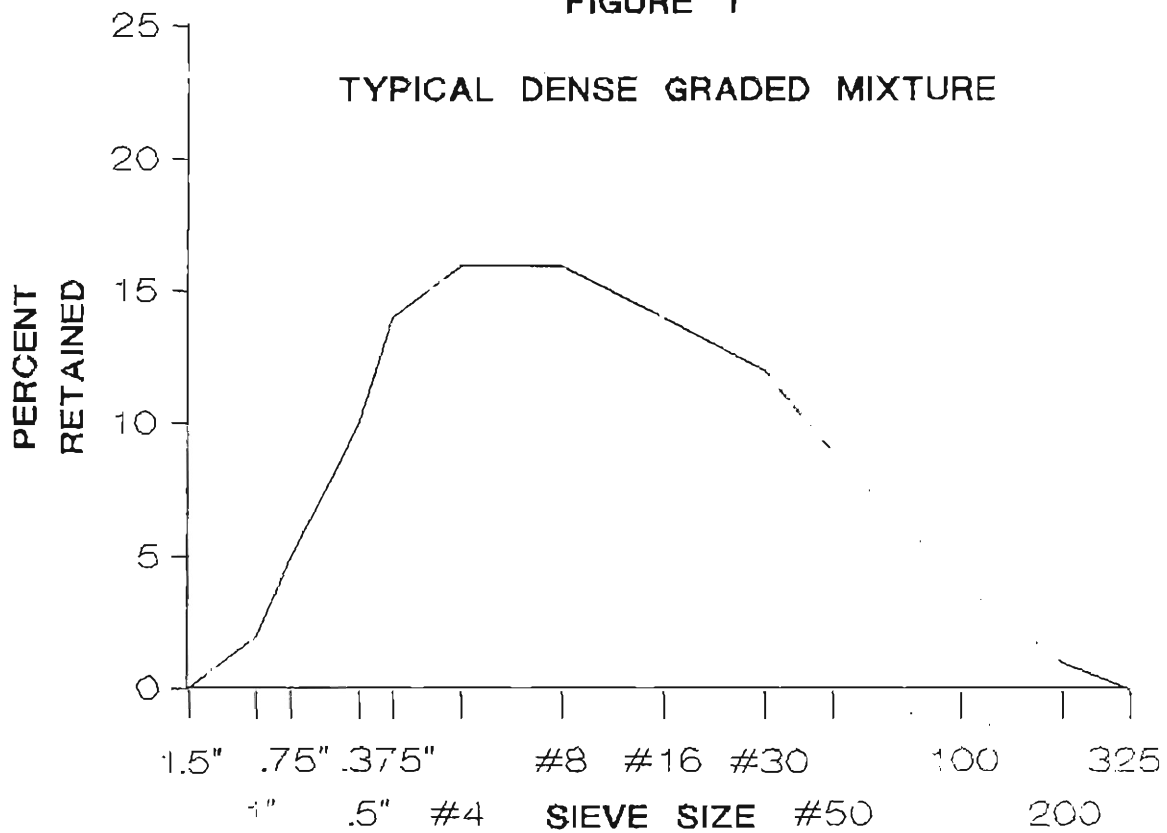
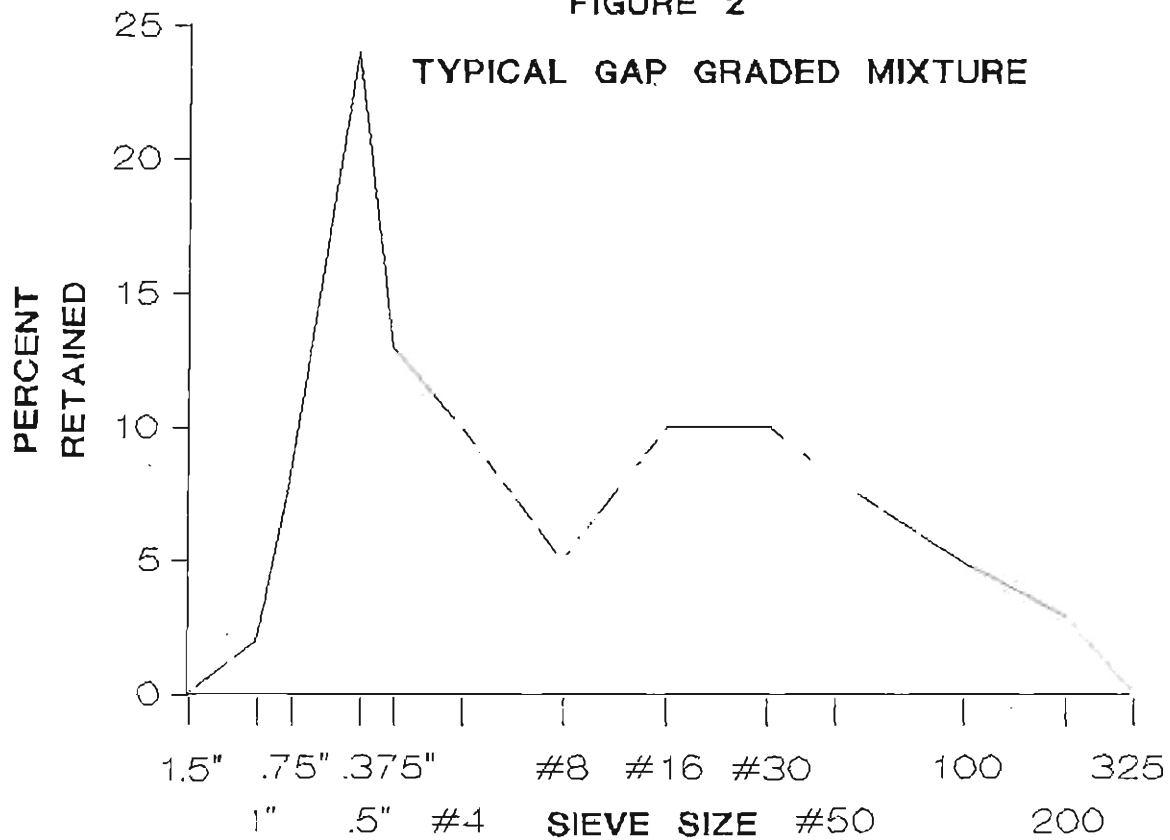


FIGURE 2



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

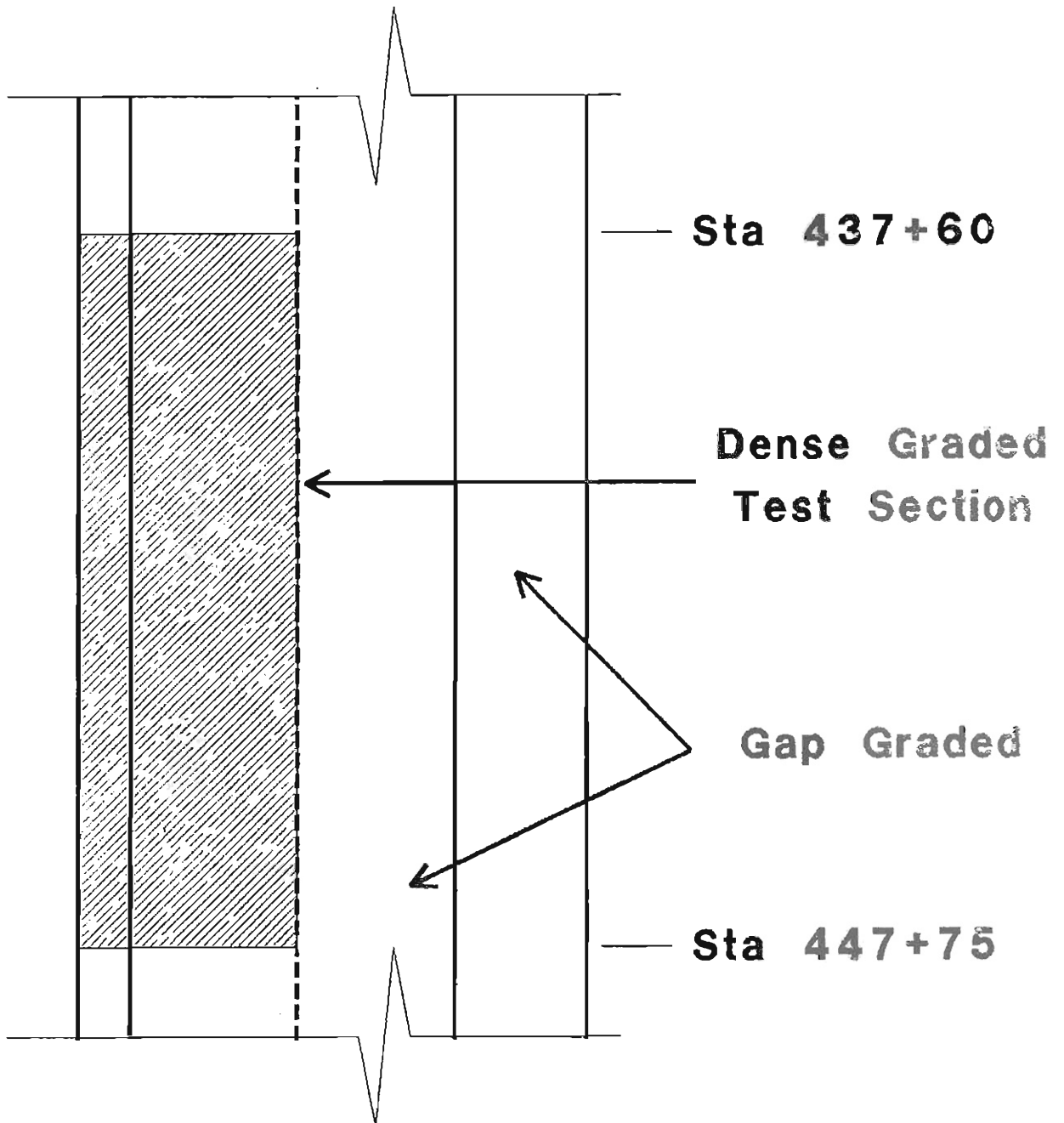
2- To incorporate the results into future pavement designs.

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	Weston, 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 Skokie 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:

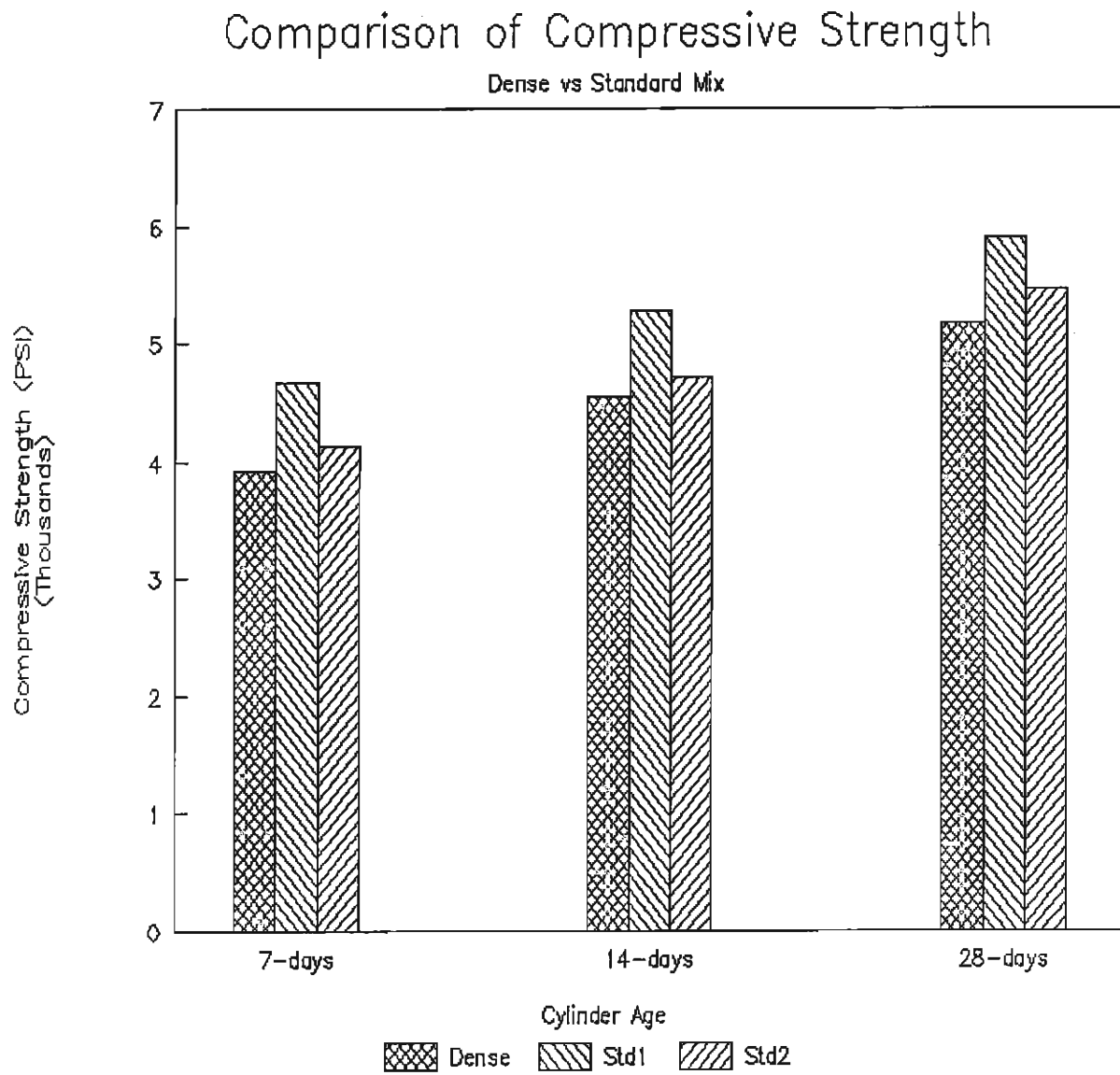


Photograph 1 & 2: A 16 foot inside lane was constructed using dense graded mixture



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

Figure 4



- 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



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

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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



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.



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
Hui Sheng Liang,
Project Engineer

Reviewed By:

Orville R. Werner II
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**

<u>Sieve Size</u>	<u>No. 57 Sample % Pass</u>	<u>ASTM C 33 #57 Specs. % Pass</u>	<u>Sand Sample % Pass</u>	<u>ASTM C 33 Sand Specs. % Pass</u>
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)

<u>Ingredient</u>	<u>Z-1604</u>	<u>Job Specification</u>
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

<u>Property</u>		
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)

<u>Ingredient</u>	<u>Z-1605</u>	<u>Job Specification</u>
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 PERFORMANCEProperty

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**

CDOH # 91087
 Item 412
 Class P
 Specified Field Strength 3000 psi
 Required Lab Strength 3750 psi

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

CONCRETE MIX PROPORTIONS (1Yd³ SSD batch weights)

Cement <u>455</u> lb	Supplier <u>Heal</u>	Type <u>1/11 LA</u>
Flyash <u>110</u> lb	Supplier <u>Western</u>	Class <u>C</u>
Coarse <u>1800</u> lb	Pit <u>Cooley - Morrison</u>	
Intermed _____ lb	Pit _____	
Sand <u>1305</u> lb	Pit <u>Centennial, Franktown</u>	
AEA <u>AES</u> oz	Manuf./Type <u>Procrete</u>	
WRA <u>PDASO</u> oz	Manuf./Type <u>Procrete</u>	
Water <u>235</u> 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) <u>WW</u>
Gradation <u>✓</u>	Gradation/FM <u>✓</u>	Gradation <u>✓</u> <u>2.75</u>
Specific Gravities <u>✓</u>	Specific Gravities <u>✓</u>	Specific Gravities <u>✓</u>
/Absorption _____	/Absorption _____	/Absorption _____
LA Abrasion <u>28.3/26.2</u>		Sand Equivalent <u>86</u>

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. Kaze Stephens 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. FLCN 083-11531

Location Hilltop - South 2 mi

District 1

Contractor Castle Rock Constr

Concrete Supplier Castle Rock Constr.

CONCRETE MIX PROPORTIONS (1Yd³ SSD batch weights)

Cement 455 lb

Supplier Ideal

Type 1/11 LA

Flyash 110 lb

Supplier Western

Class C

Coarse 1250 lb

Pit Cooley - Morrison

~~Super~~ 780 lb

Pit Centennial, Franktown

Sand 1055 lb

Pit Centennial, Franktown

AEA AE5 oz

Manuf./Type Procrete

WRA PD A-50 oz

Manuf./Type Procrete

Water 235 lb

PHYSICAL PROPERTIES OF TRIAL BATCH

Date 4-26-91

Slump 2 1/4"

Air Content 5.87%

Unit Weight 142 lb

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 _____

Specific Gravities _____

/Absorption _____

LA Abrasion 28.3 / 26.2

Gradation FM

Specific Gravities _____

/Absorption _____

Sand Equivalent _____

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

6-24-91

Reviewed by: S. Kaye Stephenson

Date: June 4, 1991

Project: FC (Cx) 063-1(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

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

DATE TRANSMITTED : 01/02/80

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
CYLINDER SET NUMBER :01

PLACED AT :352+25
PORTION :NB 30' PASS
AIR : 5. 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

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

DATE TRANSMITTED : 07/26/91

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 : 06/28/91
SLUMP : 1.5
CYLINDER SET NUMBER : 01

AIR : 5.5

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

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

DATE TRANSMITTED : 01/01/80

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 :07/11/91
SLUMP : 1.75
CYLINDER SET NUMBER :01

AIR : 6.8

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



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. <u>Paste Microstructure</u>	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. <u>Paste Hardness</u>	b. Moderately hard.	b. Moderately hard to hard.
c. <u>Paste/Aggregate Bond</u>	c. Moderately strong.	c. Moderately strong.
d. <u>Estimated Air Content</u>	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. <u>Estimated Water-to-Cementitious Ratio</u>	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.

RECOMMENDATION

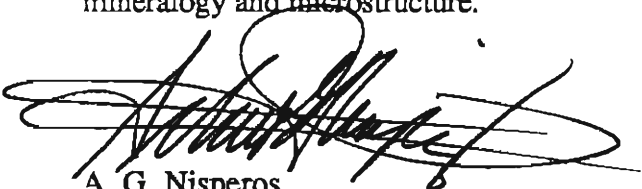
To identify and confirm alkali-silica reactions (ASR) in the two concrete cores, it is recommended that a systematic "gel fluorescence test" be undertaken.*

* 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.



A. G. Nisperos
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.



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.

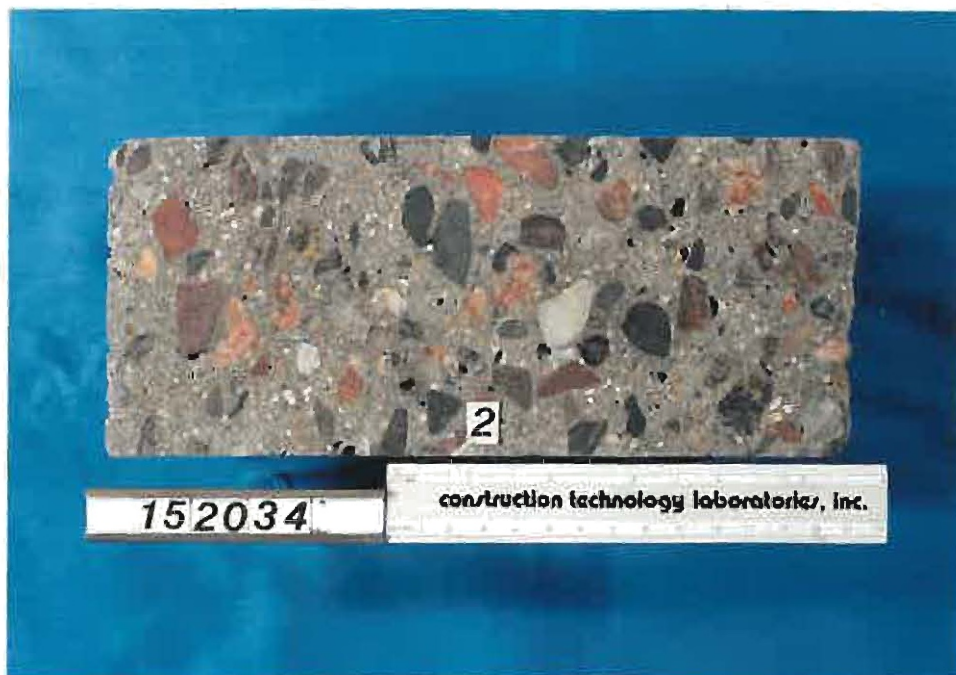


FIG. 4 LONGITUDINALLY SAWED AND LAPPED SLICE OF CORE NO. 2 SHOWING GAP GRADED COARSE AGGREGATE (LACKING 3/8-IN.-SIZE).

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

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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.

*percent by volume of paste

ESTIMATED WATER-CEMENTITIOUS RATIO: MODERATE (0.40 - 0.50).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 152034

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LOCATION: Hilltop - South 2 miles

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PROBLEM: Quality Evaluation

EXAMINED: A. G. Nisperos

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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.

*percent by volume of paste

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