STRUCTURAL CONCRETE SUBDIVISION

JUNE 1973

5000 PSI CONCRETE

PRELIMINARY INVESTIGATION OF MIX DESIGN

Introduction

This concrete investigation was initiated at the request of the Bridge Design Division to provide basic information for design and construction of cast in place post-tensioned bridge members. The concrete proportions were selected on the basis of strength, durability, and place-ability required for this type of construction.

MATERIALS

Following are listed the materials used in this investigation and their sources:

Aggregates:

3/4" Stone and Sand

Lebanon Crushed Stone, Inc.
West Lebanon, New Hampshire

Cement:

Type I

Glens Falls Portland Cement Co.
Glens Falls, New York

Water Reducing-Retarding Admixture:

Plastiment

Sika Chemical Corp.
Passaic, New Jersey

Air Entraining Admixture:

NVX

Hercules Powder Co.
Wilmington, Delaware

Procedures

The procedures used in designing the mixes closely followed those outlined in ACI Standard 211.1-70 (recommended practice for selecting proportions for normal weight concrete). The mix designs and data used in establishing them are noted in the following table.

	Mix Design #1	Mix Design #2
Coarse Aggregate lbs/cu.yd. (dry)	1862	1947
Fine Aggregate lbs/cu.yd. (dry)	1147	1067
Ratio Fine Aggregate to Total Aggregate (%)	39.6	36.9
Cement	725	725
Water-Cement Ratio	.40	.40
Slump (inches)	2-3	2-3
Air Content (percent)	6	6
Compressive Strength at 28 days, (psi)	5000	5000
Water Reducing-Retarding Admixture (oz/sk)	2½	2½

Three batches of each design were mixed in a Lancaster open pan mixer and the concrete was tested for consistency, air content, relative yield, and compressive strength. Standard 6x12 inch cylinders, cast in treated cardboard molds, were continuously moist cured and tested in compression at ages of 3, 7, 14, and 28 days.

Results

Consistency:

Air contents of all batches ranged from 5½ to 6 percent as measured by the Chace Air Indicator. These results correlated closely with the Standard pressure meter test which was occasionally used for confirmation.

Relative Yield:

The weight per cubic foot and relative yield of the two mix designs compared closely with the following results being obtained:

	Mix Design #1	Mix Design #2
Weight Per Cubic Foot (lbs)	150.58	150.30
Relative Yield (%)	99.9	100.2

Compressive Strength:

Compressive strength results are shown in the accompanying tables.

Mix Design #1

	3 Days	7 Days	14 Days	28 Days
Batch A	4368	5049	5368	5854
Batch B	4483	5438	5739	5987
Batch C	4112	4810	5085	5597
Average	4321	5099	5397	5813

Mix Design #2

	3 Days	7 Days	14 Days	28 Days
Batch A	3979	4855	5359	5615
Batch B	4253	4695	5385	5730
Batch C	4067	4828	5359	5615
Average	4100	4793	5368	5653

Summary

The concrete designed for 5000 psi proved satisfactory with laboratory results exhibiting an average strength of 5733 psi.

Both the slump and air content were within anticipated tolerances.

Conclusions & Recommendations

The mix design used in this investigation is satisfactory for field use provided rigid control be maintained relative to slump and air content. Due to the higher strengths involved, it would not be detrimental to durability to lower the air content to 5%. This would further increase compressive strength.

It should be noted that if variations in materials are anticipated, relative to cement or aggregate sources and admixture manufacturers, further investigations should be conducted in the laboratory. Also, if construction practices result in lower strengths, provisions should be made in the specifications for necessary adjustments.

Although very stiff mixes are commonly used in both pre-stressed and post tensioned concrete, complete and thorough vibration in the forms is necessary to insure proper consolidation.

6½ bag

~~RETARDER~~ TEST REPORT

Date March 14, 73

Coarse Agg. Source		Cement Source Northeast				
Fine Agg. Source		Type I				
Gradation % Passing		~~Retarder~~ Source Grace Chemical				
1"	3/8"	Trade Name WRDA				
3/4"	#4	Chemical Type				
3/8"	#16	Air Agent Source				
#4	#30	Trade Name REF			WRDA	
#8	#50	Class A Mix		2	3	4
Flats %	#100	Weights del	Per Yard	Batch	Batch	Batch
Fracture %	FM Color	AE Stone #78	1255	1255	1255	1255
Fine Agg. Sp. Gr.		Sand #30	1249	1249	1249	1249
Coarse Agg. Sp. Gr.		Cement	611	611	611	611
Predominant Mineral Composition		Water	240	240	227	223
Coarse Agg.		~~Retarder~~	4055	4055	4042	4033
Fine Agg.		WRDA. 7oz/sack				
		Yield	101	102.5	101	102.5
		Unit Weight	148.82	146.34	148.26	145.84

Yield Corrected To 6½% Air

Concrete Tests 100¾ 102¼

Bacth No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
REF	500 psi	4000 psi	Percent	Degrees	Inches	3 Day	7 Day	28 Day
~~Retarder~~	Hrs.	Hrs.						
1			5¾ chec 5¾ P		3½			
2			6 6¼ P		3¾			
3								
Average								
~~Reference~~								
4			6 hc 6½ Pass		3			
5			6 hc 6½ Pass		3¾			
6								
Average								

Water Content (Avg. % of reduction due to ~~Retarder~~ WRDA 6%

Comp. Strength (Avg. % of increase due to Retarder)	3 Day	7 Day	28 Day
Time of Setting (Avg. % of Deviation due to Retarder)	Initial		Final
Time of Setting (Avg. Increase in Hrs. due to Retarder)	Initial		Final

Notes:

7 bag

RETARDER TEST REPORT

Date March 14, 73

Coarse Agg. Source	
Fine Agg. Source	
Gradation % Passing	
1"	3/8"
3/4"	#4
3/8"	#16
#4	#30
#8	#50
Flats %	#100
Fractures %	FM Color
Fine Agg. Sp. Gr.	
Coarse Agg. Sp. Gr.	
Predominant Mineral Composition	
Coarse Agg.	
Fine Agg.	

Cement Source Northeast

Type I

~~Retarder~~ Source WRDA GRACE Chemical

Trade Name WRDA

Chemical Type

Air Agent ~~Source~~ NVX

~~Trade Name~~

	REF		WRDA	
Class (1) Mix D (2)			3	4
Weights dry	Per Yard	(2)	ce	Retarder
#2 Stone 1870	1889	1888	1888	1888
Sand 1142	1209	1209	1209	1209
Cement	658	658	658	658
Water	253	263	226	221
~~Retarder~~ Total	4008	4018	3981	3978
WRDA 7 oz/sack				
Yield	99.8 @ 6½% Air	100.2	99.6	99.8
Unit Weight	149.14	149.66	148.86	147.57

Yield corrected to 6½ % Air

99.6 99.4

Concrete Tests

Bacth No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
REFerence	500 psi	4000 psi	Percent	Degrees	Inches	3 Day	7 Day	28 Day
~~Retarder~~	Hrs.	Hrs.						
1			6¼ chace 5½ Press		3½			
2			6 c 5¼ Press		3			
3								
Average								
WRDA ~~Reference~~								
~~4~~ 1			6 chace 5¾ Press		3			
~~5~~ 2			6½ c 6¼ Press		2¾			
6								
Average								

Water Content (Avg. % of reduction due to ~~Retarder~~ WRDA) 13 %

Comp. Strength (Avg. % of increase due to Retarder) 3 Day 7 Day 28 Day

Time of Setting (Avg. % of Deviation due to Retarder) Initial Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) Initial Final

Notes:

7½

RETARDER TEST REPORT

Date *March 14, 73*

Coarse Agg. Source		Cement Source *Northeast*	
Fine Agg. Source		Type *I*	
Gradation % Passing		Retarder Source *Grace chemical*	
1"	3/8"	Trade Name *WRDA*	
3/4"	#4	Chemical Type	
3/8"	#16	Air Agent ~~Source~~ *NVX*	
#4	#30	~~Trade Name~~	
#8	#50	Class *REF*	
Flats %	#100		
Fracture %	FM Color		
Fine Agg. Sp. Gr.			
Coarse Agg. Sp. Gr.			
Predominant Mineral Composition			
Coarse Agg.			
Fine Agg.			

Weights *SSD*	Per Yard *(1)* REF	*(2)* WRDA	*(3)* WRDA	*(4)* WRDA
3/4 Stone *1805*	*1823*	*1823*	*1823*	*1823*
Sand *1109*	*1165*	*1165*	*1165*	*1165*
Cement	*705*	*705*	*705*	*705*
Water	*249*	*245*	*240*	*240*
Retarder	*39.42*	*39.33*	*39.33*	*39.33*
~~Other~~ *WRDA*				
Yield		*98.5%*	*99.5%*	*99%*
Unit Weight		*149.55*	*146.93*	*148.06*

Yield corrected to 6½% Air

Concrete Tests

Bacth No.	Proctor Penetration 500 psi Hrs.	4000 psi Hrs.	Air Content Percent	Temp. Degrees	Slump Inches	Compressive Strength 3 Day	7 Day	28 Day
REF ~~Retarder~~								
1			*5½ Chace 5½ Press*		*3¾*			
2			*5¼ chace 5½ Press*		*3*			
~~3~~								
Average								
WRDA ~~Reference~~								
~~4~~ *1*			*6½ chace 6½ Press*		*3*			
~~5~~ *2*			*5½ chace 6 Press*		*3½*			
6								
Average								

Water Content (Avg. % of reduction due to ~~Retarder~~ *WRDA*) *2%*

Comp. Strength (Avg. % of increase due to Retarder) 3 Day 7 Day 28 Day

Time of Setting (Avg. % of Deviation due to Retarder) Initial Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) Initial Final

Notes:

Age	6½ Ref	6½ WRDA	6½ %	7 Ref	7 WRDA	7 %	7½ Ref	7½ WRDA	7½ %
5	2622	3259	124	3339	3573	107	3449	3613	105
7	3356	3568	106	3506	4045	115	3644	3820	105
14	3347	3700	111	3798	4333	114	4019	4010	100 99.8
28	3802	4311	113	4240	4762	112	4541	4528	100 99.7

Aggregate - Lebanon Crushed Stone Inc.
Cement - Northeast Type I
Admixture - WRDA
Air - NVX

High Compressive Strength Concrete

Age of Concrete in Days		Reference Mix						Water Reducing Mix					
		Sacks of Cement per Yard											
		6½		7		7½		6½		7		7½	
		Mix No 1	Mix No 2	Mix No 1	Mix No 2	Mix No 1	Mix No 2	Mix No 1	Mix No 2	Mix No 1	Mix No 2	Mix No 1	Mix No 2
5	LBS	78,750	69,750	90,750	98,000	95,750	99,250	93,750	90,500	99,250	102,750	100,000	104,250
	PSI	2776	2467	3210	3467	3387	3511	3316	3201	3510	3635	3537	3688
7	LBS	95,000	94,750	95,250	103,000	102,250	103,750	105,750	96,000	112,250	116,500	109,250	106,750
	PSI	3360	3351	3369	3643	3617	3670	3740	3395	3970	4120	3864	3776
14	LBS	97,750	91,500 Horizontal Break	103,500	111,250	111,250	116,000	103,250	106,500	118,500	126,500	117,250	109,500
	PSI	3457	3236	3661	3935	3935	4103	3652	3747	4191	4474	4147	3873
28	LBS	114,000	101,000	116,250	123,500	129,500	127,250	124,000	119,750	135,750	133,500	129,750	126,250
	PSI	4032	3572	4112	4368	4580	4501	4386	4236	4802	4722	4589	4466

Date March 12, 73

Laboratory Calculated Concrete Design

Class ___ Concrete; Item _____

For use on all projects in area using this source
Concrete Mix from Lebanon Stone

Aggregate from:

1 Stone Lebanon Crushed Stone SPecific Gravity _____

2 Stone W. Lebanon NH SPecific Gravity 2.94

Sand _____ SPecific Gravity 2.71

Design:

6.5 Bags of Cement Per Yard
40 % Sand to total aggregate volume
6.5 % Air Entrainment
100 % Pea Stone to total stone volume
5.25 Gallons H_2O Per Sack Cement

Air Entrainment Cement $\frac{6.5 \times 94}{3.15 \times 62.4}$ = 3.108 C.F. = 611 lbs.

5.25 Gallons H_2O Per Bag Cement $\frac{6.5 \times 5.25}{7.48}$ = 4.562 C.F. = 34.125 Gals

6.5 % Air Entrainment 6.5 % x 27.000 = 1.755 C.F.

Sand (40 % Sand to total aggregate volume) = 7.030 C.F.

2 Stone (100 % of total stone volume) = 10.545 C.F.

1 Stone = :: C.F.
27.000 C.F.

Dry Weights:

Sand = 7.030 X 2.71 X62.4= 1189 Lbs. 6

#2 Stone = 10.545 X 2.94 X62.4= 1935 Lbs.

#1 Stone = _____ X _____ X62.4= _____ Lbs.

Mix:

_____" Stone = _____ Lbs. 6605

_____" Stone = _____ Lbs. 1075

Sand = _____ Lbs.

Cement = _____ Lbs.

Gallons H_2O Per Yd. = _____

Adjust for Moisture

Date March 12

Laboratory Calculated Concrete Design

Class A Concrete; Item 501.20

For use on all projects in area using this source
Concrete Mix from _____

Aggregate from:

1 Stone _____ SPecific Gravity _____

2 Stone Lebanon Crushed Stone SPecific Gravity 2.94

Sand Lebanon NH SPecific Gravity 2.71

Design:

7 Bags of Cement Per Yard
40 % Sand to total aggregate volume
6.5 % Air Entrainment
100 % Pea Stone to total stone volume
5.25 Gallons H_2O Per Sack Cement

Air Entrainment Cement $\frac{7 \times 94}{3.15 \times 62.4}$ = 3.348 C.F. = 658 lbs.

5.25 Gallons H_2O Per Bag Cement $\frac{7.0 \times 5.25}{7.48}$ = 4.913 C.F. = 36.75 Gals

6.5 % Air Entrainment 6.5 % x 27.000 = 1.753 C.F.

Sand (40 % Sand to total aggregate volume) = 6.794 C.F.

2 Stone (100 % of total stone volume) = 10.190 C.F.

1 Stone = _____ C.F.
27.000 C.F.

Dry Weights:

Sand = 6.794 X 2.71 X62.4 = 1149 Lbs.

#2 Stone = 10.190 X 2.94 X62.4 = 1870 Lbs.

#1 Stone = _____ X _____ X62.4 = _____ Lbs.

Mix:

_____ " Stone = _____ Lbs.

_____ " Stone = _____ Lbs.

Sand = _____ Lbs.

Cement = _____ Lbs.

Gallons H_2O Per Yd. = _____

Sand 638
1030

Adjust for Moisture

Date March 12

Laboratory Calculated Concrete Design

Class A Concrete; Item _____

For use on all projects in area using this source
Concrete Mix from _____

Aggregate from:

1 Stone _____ SPecific Gravity _____

2 Stone Lebanon Crushed Stone SPecific Gravity 2.94

Sand Co. Lab Mill SPecific Gravity 2.71

Design:

7.5 Bags of Cement Per Yard
40 % Sand to total aggregate volume
6.5 % Air Entrainment
100 % Pea Stone to total stone volume
5.25 Gallons H_2O Per Sack Cement

Air Entrainment Cement $\frac{7.5 \times 94}{3.15 \times 62.4}$ = 3.536 C.F. = 704 lbs.

5.25 Gallons H_2O Per Bag Cement $\frac{7.5 \times 5.25}{7.48}$ = 5.264 C.F. = 39.375 Gals

6.5 % Air Entrainment 6.5% x 27.000 = 1.755 C.F.

Sand (40% Sand to total aggregate volume) = 6.558 C.F.

2 Stone (100 % of total stone volume) = 9.837 C.F.

1 Stone = :: C.F.

27.000 C.F.

Dry Weights:

Sand = 6.558 X 271 X62.4= 1109 Lbs.

#2 Stone = 9.837 X 2.94 X62.4= 1805 Lbs.

#1 Stone = _____ X _____ X62.4= _____ Lbs.

Mix:

_____" Stone = _____ Lbs. 61.6

_____" Stone = _____ Lbs. 100.3

Sand = _____ Lbs.

Cement = _____ Lbs.

Gallons H_2O Per Yd. = _____

Adjust for Moisture