PRELIMINARY INVESTIGATION OF LIGHTWEIGHT CONCRETE

Report R71-3

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VERMONT DEPARTMENT OF HIGHWAYS

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INTRODUCTION

This lightweight concrete investigation was initiated at the request of the Bridge Design Division to provide basic information for design and construction. The materials included in this study are locally produced and representative of those expected to be used in this area when lightweight concrete is specified. Of prime interest are results concerning weight per cubic foot of concrete, compressive strength of molded concrete cylinders, and any peculiarities of lightweight concrete.

MATERIALS

The Coarse Aggregate used in this investigation was produced by Vermont Lightweight Aggregate Corporation, Castleton, Vermont. Two gradations were used as shown in the table below.

The Fine Aggregate was supplied by Lebanon Crushed Stone Inc., West Lebanon, New Hampshire.

The average grading of the coarse and fine aggregates are noted as follows:

	Coarse Aggregate		Fine Aggregate	
	Gradation #1	Gradation #2		
Sieve Size	% Passing	% Passing	Sieve Size	% Passing
1"	--	100	3/8"	100
3/4"	100	97	#4	99
3/8"	14	37	#8	91
#4	4	12	#16	67
#8	3	7	#30	38
			#50	13
			#100	4
			FM	2.87

The cement used in all batches was Type I as furnished by the Glens Falls Portland Cement Company, Glens Falls, New York.

Hercules Powder Company, Wilmington, Delaware manufactured the NVX (air entraining admixture) which was used in sufficient quantity to obtain the desired air content. No other admixtures were used.

PROCEDURES

The procedures used in designing the mixes closely followed those outlined in ACI Standard 211.2-69 (Recommended Practice for Selecting Proportions for Structural Lightweight Concrete).

Quantities of cement, coarse aggregate and fine aggregate were varied to obtain minimum unit weights while maintaining workability.

A Lancaster open pan mixer was used under laboratory conditions and the concrete was tested for slump, air content, unit weight and compressive strength. Unit weight tests were performed using a 1/2 cubic foot measure. Standard 6x12 inch cylinders, cast in treated cardboard molds, were continuously moist cured and tested in compression at ages of 7 and 28 days.

RESULTS

Structural lightweight concretes are defined by the American Concrete Institute as "concretes having a 28 day compressive strength in excess of 2500 psi and a 28 day air-dry unit weight, not exceeding 115 pcf".

AASHO Specifications allow the unit weight to reach a maximum of 120 pcf in the plastic state and 115 pcf in the dry state for concrete having a 28 day compressive strength of 4000 psi. This specification also states that "the plastic concrete shall contain six to nine percent of entrapped and purposefully entrained air".

None of our tests resulted in recommended requirements for lightweight concrete as set forth in AASHO. If the compressive strength exceeded minimum requirements, then the unit weight exceeded desired limits. Several reasons for these factors are evident.

Fine aggregate for lightweight concrete should have a maximum dry loose weight of 70 lbs/cu. ft. This testing program utilized normal weight fine aggregate having a dry loose weight of 105 lbs/cu. ft. Although this discrepancy makes the concrete heavier, it is a common practice and its effect can usually be surmounted.

The coarse aggregate for this study was composed of two separate gradations. All batches incorporated Gradation #1 (see gradation chart) with the exception of Batch #4 which utilized Gradation #2.

Our mixes had an air content of from five to seven percent. For lightweight concrete, six to nine percent is recommended and the higher percentages would result in lighter weight specimens.

Finally, all unit weights shown in the following table refer to the plastic concrete rather than the air-dry concrete, thus indicating the weight at which the sample is heaviest.

Following is listed the batching data and results:

Batch Number	1	2	3	4	5	6
Coarse Aggregate (lb/cy)	848	848	1448	933	933	933
Fine Aggregate (lb/cy)	1280	1660	745	1361	1361	1281
Cement (lb/cy)	564	564	564	611	611	705
Water-Theoretical Quant. (lb/cy)	426	288	288	300	300	300
Water-Actual Quant. (lb/cy)	301	340	324	322	306	310
Weight-Theoretical (lb/cf)	115	124	113	119	119	119
Weight-Actual (lb/cf)	122	122	115	115	119	119
Slump (in.)	4	2 1/2	2 1/4	2 3/4	2 3/4	2 3/4
Air Content (%)	6	5	5 1/2	6	6	7
Relative Yield (%)	91	103	99	104	100	100
Compressive Strength 7 day (psi)	3793	2844	2370	2759	3029	3506
Compressive Strength 28 day (psi)	4179	3587	2862	3484	3684	4362

DISCUSSION

Batch #1, being a preliminary mix, contained a theoretical cement quantity equivalent to six sacks per cubic yard. However, the yield was low and resulted in a higher unit weight and a higher cement factor than was expected. Although it was a workable mix, the slump was 4" and the cement quantity was equivalent to 6.6 sacks per cubic yard.

Batch #2 was composed of the same design weights as the previous batch except for an increase in the amount of fine aggregate for the purpose of increasing the yield. The result was a workable mix which did not appear to be heavily sanded. However, the weight of the concrete was much too high.

Batch #3 was also a 6 sack/cy mix but with an increased quantity of the lightweight coarse aggregate. An excellent unit weight was obtained but at the sacrifice of strength and workability.

Batches #4 and #5 were identical 6 1/2 sacks/cy mixes but with each utilizing different coarse aggregate gradations. Some variation in weight and strength is noted but no conclusions should be made on the basis of so few cylinders.

Batch #6 was mixed using a 7 1/2 sacks/cy cement quantity. This was responsible for higher strengths. The yield was good, but the weight was higher than desired.

CONCLUSIONS AND RECOMMENDATIONS

Lightweight concrete in our highway bridge program might be employed if special precautions are taken. Rigid quality control must be ensured and handling and placement operations be refined to insure homogeneity.

It is recommended that further tests be performed using a cement content of 7 sacks/cy along with a water-reducing agent and an average air content of 8%.

A comparison should be made regarding the weight differential between wet unit weight as performed in this study and air-dry unit weight as required in ASTM C 567-69. This standard method was not used due to the assumption that the wet weight would exceed the dry weight and be indicative of our mixtures. Finally, an evaluation of durability should be undertaken as this requirement is as important as weight and strength. The correct ingredients properly proportioned will result in many of the desired properties being achieved.