Louisiana Highway Research

DURABILITY OF LIGHTWEIGHT CONCRETE

PHASE I

CONCRETE TEMPERATURE STUDY

Louisiana Department of Highways – Research & Development Section

DURABILITY OF LIGHTWEIGHT CONCRETE
PHASE I - CONCRETE TEMPERATURE STUDY

by

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ABSTRACT

This report describes a study conducted to determine the temperature gradient throughout the depth of a six inch concrete bridge deck. The bridge deck selected for study was constructed using lightweight concrete for the center spans and sand and gravel concrete for the remaining spans. This enabled us to determine the difference, if any, in the temperature gradient for the two types of concrete.

Thermocouples were placed in the concrete at one inch intervals beginning one-half inch from the top of the slab with the last point being one-half inch from the bottom of the slab. A continuous recording was made of the thermocouples in both types of concrete and two themocouples were used to record air temperature. A one year cycle of temperatures were recorded and analyzed.

The results of the study indicated that lightweight concrete has a greater temperature differential from top to bottom than does sand and gravel concrete, although the top one-half inch of both concretes were usually at the same temperature. The average maximum differential between the top one-half inch and the bottom one-half inch was 26 degrees for the lightweight concrete and 13 degrees for the sand and gravel concrete. In addition, there was 41 days during which freezing temperatures occurred in both concretes. However, the interior of the lightweight concrete was normally two to three degrees warmer than the sand and gravel concrete.

INTRODUCTION

This study was undertaken in order to determine the actual temperatures encountered in a concrete bridge deck during a one year period. The main interest was to ascertain the temperature gradient throughout a six inch concrete deck for both sand and gravel concrete and lightweight concrete. It was felt that since lightweight concrete performed as a better insulating material than sand and gravel concrete, that the interior of the lightweight concrete deck should be warmer in the winter months and cooler in the summer months than the sand and gravel concrete. This could be very important during freezing conditions.

The bridge selected for study was one which had both types of concrete in the bridge deck. The longer spans were lightweight concrete while the shorter end spans were sand and gravel concrete. The location of the bridge was near Ruston, Louisiana where La. 408 crosses over Interstate 20. Ruston, Louisiana is located in the northern part of the State and normally has several months during which freezing temperatures occur.

The recording device was installed during the month of January, 1967 and temperature data was obtained until February, 1968.

METHODOLOGY

Recording Apparatus - All temperatures were recorded with a Honeywell 24 point recorder with temperature readings taken every 30 seconds from thermocouples placed in the slab of the bridge deck. The thermocouples were placed in both the lightweight concrete and the sand and gravel concrete sections of the bridge deck at points 1/2 inch, 1 1/2 inches, 2 1/2 inches, 3 1/2 inches, 4 1/2 inches, and 5 1/2 inches from the top of the slab. This was accomplished by cutting a hole in the slab, positioning the thermocouples and patching the hole with fresh concrete. The same type of concrete was used to patch the hole as was originally poured in the slab.

Chart Analysis - Temperatures were recorded permanently on a chart graduated in F°. Readings were printed by the recorder every 30 seconds beginning at Point 1 and continuing to Point 24, giving a 12 minute cycle for the 24 point coverage. Only 14 points were used in this study, 6 in each type of concrete and 2 for air temperatures. The other 10 points read ambient temperatures inside the recorder. The recorder ran continuously throughout the study period except for the time needed to change charts, which was approximately every 10 days.

Since each chart contained 10 days of temperature recordings, it was necessary to divide them into individual days. The air temperature and the temperature at the various depths in the slab were recorded at the time of maximum and minimum temperature for each day for each type of concrete. From these daily maximum and minimum temperatures the average monthly maximum and minimum daily temperatures were obtained for each point in both types of concrete. Table 1 and Table 2 show the average monthly maximum and minimum daily temperatures for the lightweight concrete and the sand and gravel concrete respectfully.

Table 1

Average Monthly Maximum and Minimum Daily Temperatures - Lightweight Concrete Slab

Month and Year	Slab Temperatures at Various Depths* - F°												Air Temperatures	
	1/2 inch		1 1/2 inches		2 1/2 inches		3 1/2 inches		4 1/2 inches		5 1/2 inches			
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	at Max	at Min
January 1968	57	34	52	36	49	37	47	37	46	37	47	37	50	35
February 1968	63	30	57	33	53	34	50	34	49	34	49	34	49	34
March 1967	92	51	85	53	79	54	76	55	74	55	73	54	72	50
April 1967	100	62	93	65	87	65	83	66	81	66	80	65	78	60
May 1967	107	63	102	65	95	66	88	66	88	66	86	66	81	61
June 1967	121	74	113	76	106	77	101	78	98	78	96	77	89	71
July 1967	116	72	107	74	100	75	96	75	93	75	92	74	87	70
August 1967	116	73	108	74	101	76	97	76	94	76	93	75	85	70
September 1967	100	64	94	66	89	67	85	67	84	67	83	67	81	64
October 1967	93	54	86	56	80	57	76	57	75	58	75	57	75	52
November 1967	72	43	67	45	63	46	61	47	59	47	61	46	63	43
December 1967	58	36	54	38	52	39	50	39	50	40	50	39	53	37

* All depths measured from top of slab.

Table 2

Average Monthly Maximum and Minimum Daily Temperatures - Sand and Gravel Concrete Slab

Month and Year	Slab Temperatures at Various Depths* - F°												Air Temperatures	
	1/2 inch		1 1/2 inches		2 1/2 inches		3 1/2 inches		4 1/2 inches		5 1/2 inches			
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	at Max	at Min
January 1968	56	34	54	35	52	35	51	35	50	35	50	35	49	34
February 1968	62	30	59	31	57	31	55	31	54	31	53	31	49	31
March 1967	90	51	87	51	84	51	83	52	81	52	80	52	72	50
April 1967	97	62	94	62	91	62	89	63	88	63	86	62	78	60
May 1967	107	62	103	62	100	62	98	63	96	63	94	63	81	61
June 1967	118	73	115	74	111	74	109	74	107	74	105	74	89	71
July 1967	112	71	109	71	106	71	103	72	101	72	100	72	87	70
August 1967	113	72	106	72	106	72	104	73	102	73	101	73	88	70
September 1967	99	64	96	64	93	64	92	64	90	65	89	65	88	64
October 1967	91	53	88	54	85	54	83	54	82	54	81	54	75	52
November 1967	71	43	69	44	67	44	65	44	64	44	64	44	63	43
December 1967	58	37	56	37	54	37	53	37	53	37	53	38	53	37

*All depths measured from top of slab

DISCUSSION OF RESULTS

Time of Maximum and Minimum Daily Temperatures

The maximum daily temperatures in the lightweight concrete and the maximum daily temperatures in the sand and gravel concrete occurred simultaneously as did the minimum daily temperatures of the two types of concrete. The time of the maximum daily temperatures of the two types of concrete varied from 12 noon to 7:00 P.M. while the time of the minimum daily temperature varied from 12 midnight to 8:00 A.M.

Average Monthly Maximum Daily Temperatures

Figure 1 shows the average monthly maximum daily temperature at each point in the lightweight concrete slab while Figure 2 shows the average monthly maximum daily temperatures in the sand and gravel concrete slab. It can be seen by comparison that the lightweight concrete had a greater range in temperatures between the top and bottom points of the slab than the sand and gravel concrete. The greatest difference occurred in the month of June where the lightweight concrete had a 25°F difference between the 1/2 inch point and the 5 1/2 inches point while the sand and gravel concrete had a difference of only 11°F between the same two points. Figures 1 and 2 also show the average monthly daily air temperatures at the time of average monthly maximum daily temperatures in the slab. The air temperature was generally lower than any temperatures encountered in the slab of either type of concrete.

Average Monthly Minimum Daily Temperatures

The range of the average monthly minimum daily temperatures of the lightweight concrete and the sand and gravel concrete was not significantly different. However, the average monthly minimum daily temperature at the point 1/2 inch from the top of the slab was always lower than the average monthly minimum daily temperature at the point 5 1/2 inches from the top of the slab (1/2 inch from the bottom of the slab) in both types of concrete. Figure 3 shows the average monthly minimum daily temperatures for the point 1/2 inch from the top of the slab and 5 1/2 inches from the top of the slab, as well as the average monthly daily air temperatures for the lightweight concrete. Figure 4 shows the same information for the sand and gravel concrete.

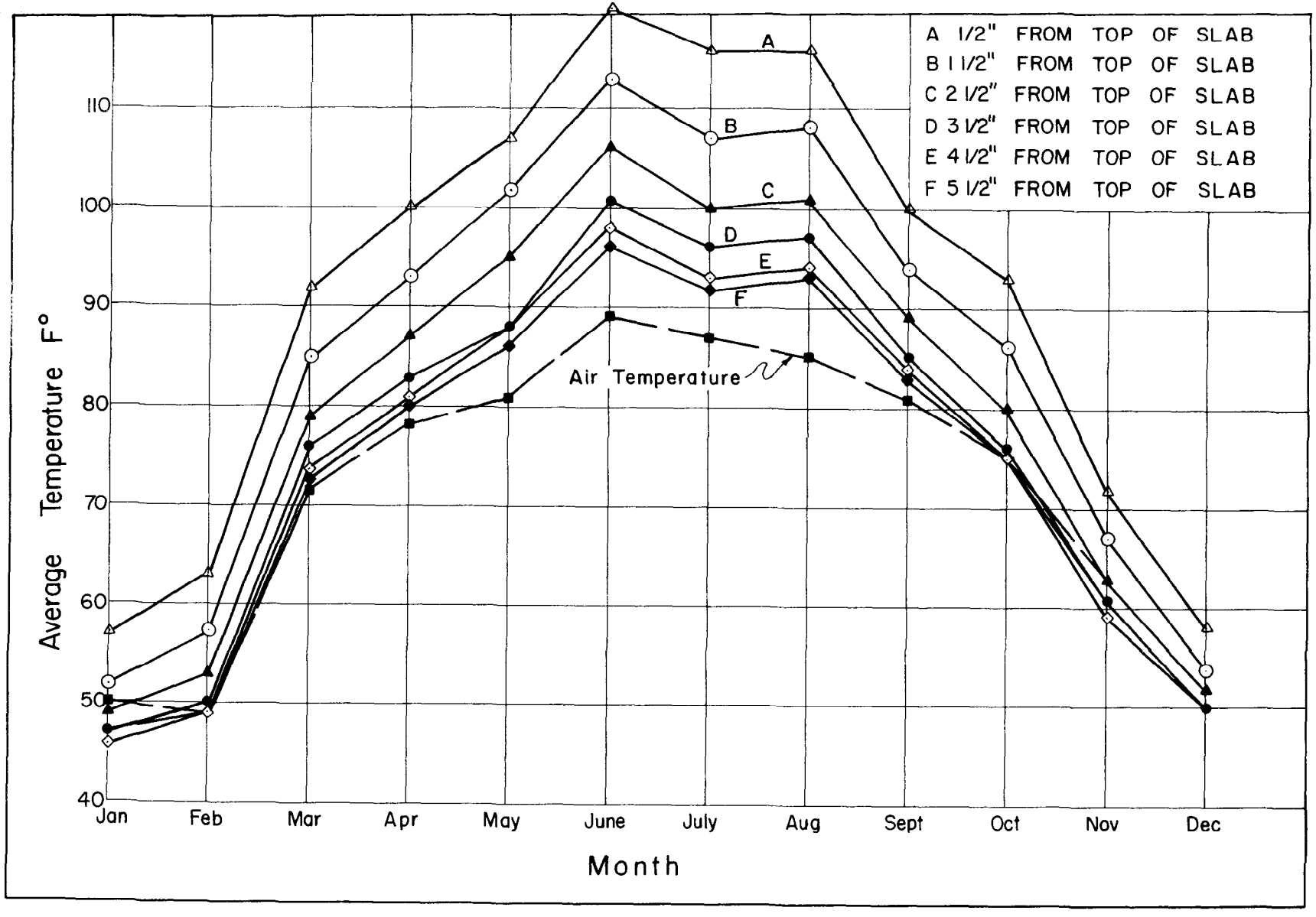

Figure 1 - Average Monthly Maximum Daily Temperatures at Various Depths in Lightweight Concrete

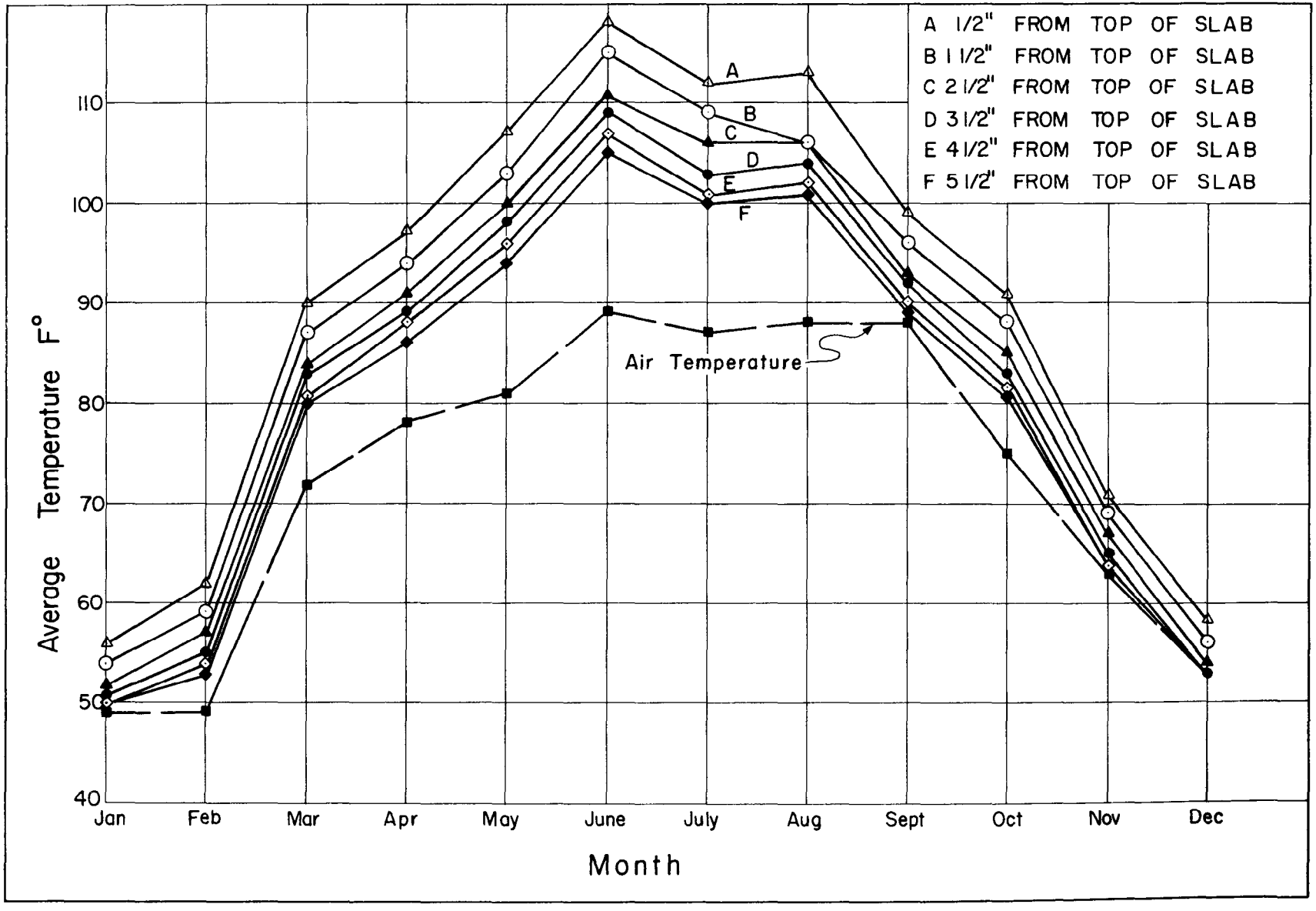

Figure 2 - Average Monthly Maximum Daily Temperatures at Various Depths in Sand and Gravel Concrete

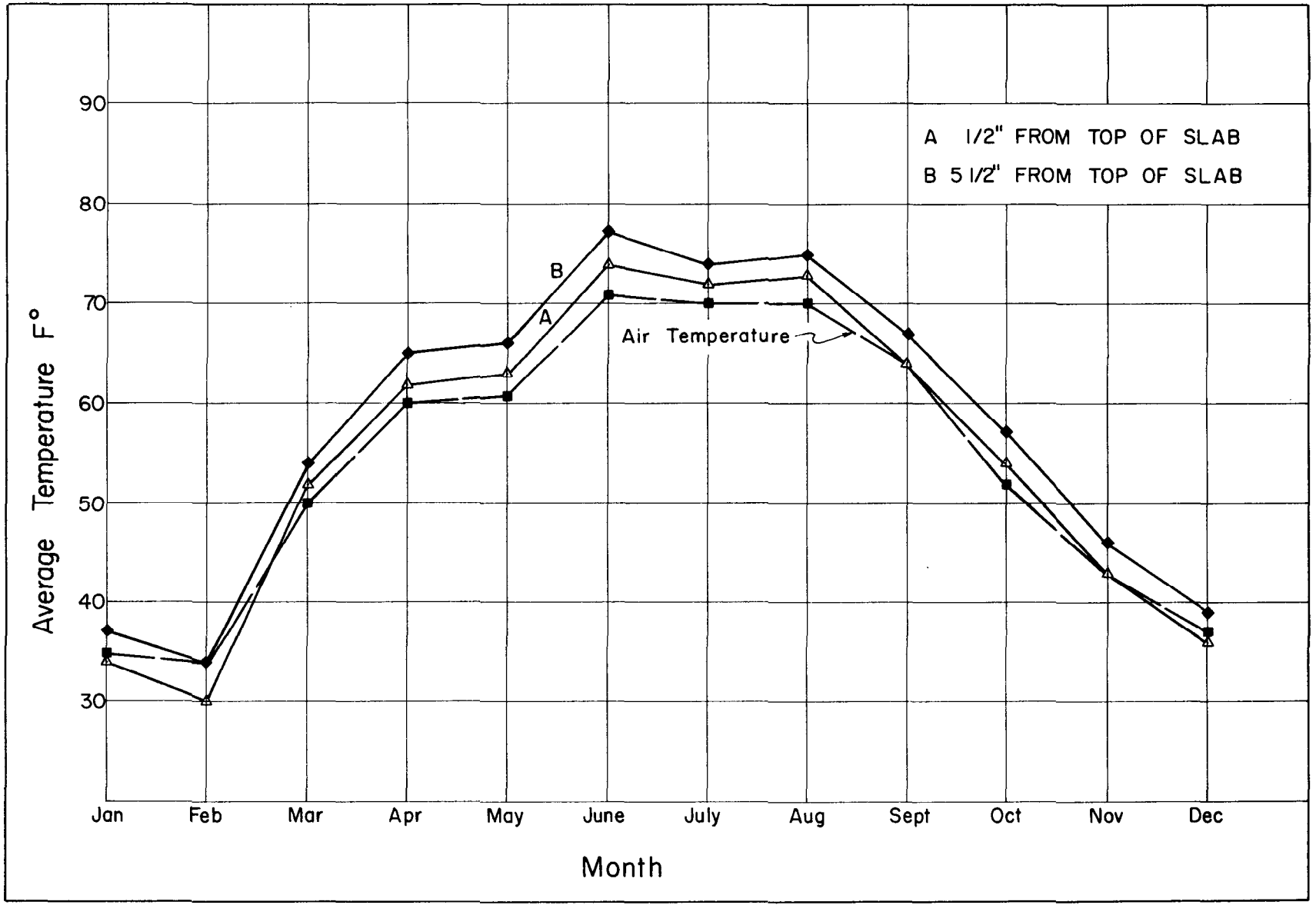

Figure 3 - Average Monthly Minimum Daily Temperatures in Lightweight Concrete

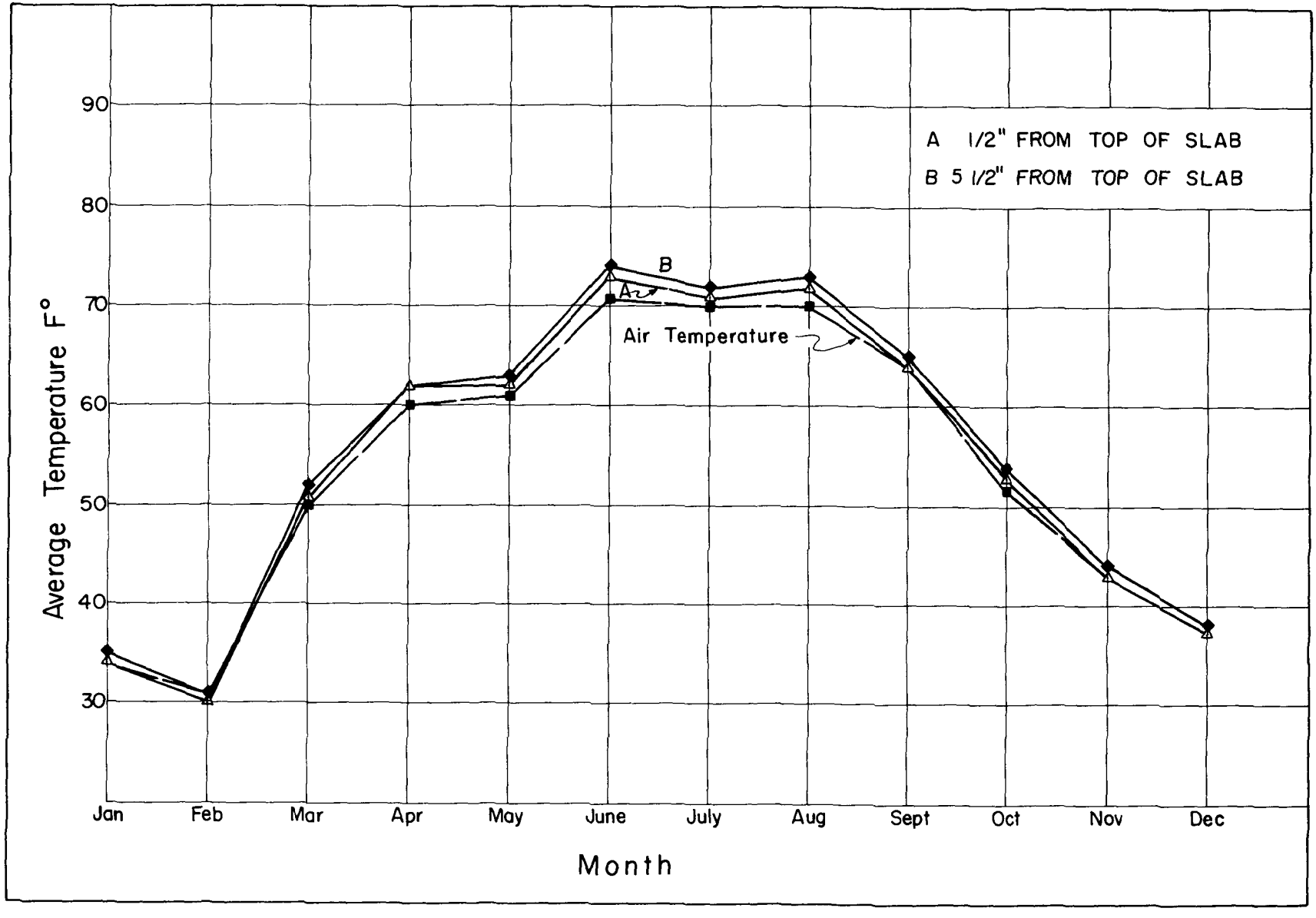

Figure 4 - Average Monthly Minimum Daily Temperatures in Sand and Gravel Concrete

Table 3
Freezing Temperature Data

Date	Type Concrete	Temperatures at Various Depths* in Slab - F°						Air
		1/2 inch	1 1/2 inch	2 1/2 inch	3 1/2 inch	4 1/2 inch	5 1/2 inch	Temperature F°
1/1/68	Light Weight	31	32	32	32	32	32	31°
1/1/68	Sand and Gravel	31	31	31	31	31	31	31°
1/2/68	L W	31	31	32	32	32	32	31°
1/2/68	S G	31	31	31	31	31	31	31°
1/5/68	L W	32	32	33	33	33	32	31°
1/5/68	S G	32	32	32	32	32	33	31°
1/7/68	L W	17	19	20	20	21	20	16°
1/7/68	S G	16	17	17	18	18	18	16°
1/8/68	L W	14	15	16	16	17	17	15°
1/8/68	S G	13	14	14	14	14	15	15°
1/9/68	L W	30	30	30	29	29	30	30°
1/9/68	S G	31	30	30	30	30	30	30°
1/10/68	L W	29	31	32	32	32	32	29°
1/10/68	S G	29	30	30	31	31	31	29°
1/11/68	L W	25	26	26	28	28	28	26°
1/11/68	S G	24	25	25	26	26	26	26°
1/12/68	L W	26	28	30	30	31	30	29°
1/12/68	S G	26	26	27	29	27	28	29°
1/13/68	L W	21	22	24	25	25	25	24°
1/13/68	S G	21	22	22	22	23	23	24°
1/14/68	L W	20	21	22	23	23	23	21°
1/14/68	S G	20	20	20	20	21	21	21°
1/15/68	L W	23	25	26	28	28	28	26°
1/15/68	S G	24	25	26	28	28	28	26°
1/16/68	L W	25	27	28	29	29	29	26°
1/16/68	S G	25	26	26	26	26	26	26°
1/17/68	L W	27	29	30	31	31	31	28°
1/17/68	S G	27	28	28	28	28	28	28°
1/18/68	L W	32	34	35	36	36	36	32°
1/18/68	S G	33	33	33	34	34	34	32°
1/23/68	L W	33	35	37	38	38	37	31°
1/23/68	S G	32	33	34	34	34	34	31°
1/24/68	L W	23	26	27	28	29	28	25°
1/24/68	S G	23	23	24	24	24	25	25°
1/25/68	L W	29	30	32	32	33	32	30°
1/25/68	S G	30	30	31	31	31	31	30°

* All depths measured from top of slab

CONCLUSIONS

1 For each day of the study period the maximum daily temperature of the lightweight concrete and the maximum daily temperature of the sand and gravel concrete occurred simultaneously. The minimum daily temperature in the lightweight concrete and the minimum daily temperature in the sand and gravel concrete also occurred simultaneously.

2. The range of the average monthly maximum daily temperatures throughout the depth of the concrete slab was greater in the lightweight concrete than in the sand and gravel concrete during the study period. This range was greater during the summer months.

3. The range of the average monthly minimum daily temperatures throughout the depth of the lightweight concrete slab and the sand and gravel concrete slab did not vary significantly during the study period, but the average monthly minimum daily temperature at the point ½ inch from the top of the slab was always lower than the average monthly minimum daily temperature at the point 5 ½ inch from the top of the slab (½ inch from the bottom of the slab) in both types of concrete.

4. Freezing temperatures in both the lightweight concrete and the sand and gravel concrete were recorded on 41 days of the study period and occurred primarily during January and February. However, during the freezing conditions, the lightweight concrete was normally two to three degrees warmer in the interior of the slab than was the sand and gravel concrete.

5. The maximum temperature recorded during the study period was 129°F and was recorded in both the lightweight concrete and the sand and gravel concrete, ½ inch from the top of the slab.

6. The minimum temperature recorded during the study period was 13°F and was also recorded in both the lightweight concrete and the sand and gravel concrete, ½ inch from the top of the slab.

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