EVALUATION OF FLY ASH CONCRETE SUBJECT TO RAPID FREEZING AND THAWING

PART III

Submitted to
The Dolese Company
20 N.W. 13th Street
Oklahoma City, Oklahoma

by

Fears Structural Engineering Laboratory
School of Civil Engineering and Environmental Science
University of Oklahoma
Norman, Oklahoma

February 1983

FEARS STRUCTURAL ENGINEERING LABORATORY
School of Civil Engineering and Environmental Science
University of Oklahoma
Norman, Oklahoma 73019

TABLE OF CONTENTS

	Page
LIST OF FIGURES AND TABLES	ii
INTRODUCTION	1
TEST DETAILS	2
Test Specimens	2
Testing Equipment	2
TESTING PROCEDURE	3
TEST DATA	4
Dynamic Young's Modulus	4
Relative Dynamic Modulus of Elasticity	4
Durability Factor	5
TEST RESULTS	5
APPENDIX A	9

LIST OF FIGURES

Figure	Page
1. Relative Dynamic Modulus of Elasticity	8

LIST OF TABLES

Table	Page
1. Average Relative Dyanmic Modulus of Elasticity Values.	7
2. Durability Factors	7
A.1 Materials	10
A.2 Mix Proportions per Cubic Yard	10
A.3 Batch Test Data	11
A.4 Specimen Data.	11
A.5 Frequency Related Data, Series - A	12
A.6 Frequency Related Data, Series - B	14

INTRODUCTION

Tests were performed at the Fears Structural Engineering Laboratory, University of Oklahoma, Norman, Oklahoma for the Dolese Company of Oklahoma City to determine the resistance of a normal weight concrete mix to rapid freezing and thawing. The test procedure conformed to ASTM C666-77 Standard Method of Testing for Resistance of Concrete to Rapid Freezing and Thawing, Method A. The materials for the test as well as mix proportions by weight were provided by the Dolese Company.

A total of eight specimens were cast for the specified mix design and were subjected to three hundred cycles of freezing and thawing. Fundamental frequency measurements were taken at various points during the test period and from these measurements quantitative values were computed and compared. The specimens were cast from two batches using the same design mix proportions and are referred to as Series A and Series B. There were four specimens in each series. A complete description of the testing procedure and test results follows.

TEST DETAILS

Test Specimens. Test specimens were cast in specially made plywood forms with nominal dimensions of 4 in. by 4 in. by 16 in. The concrete materials and mix proportions used are shown in Tables A.1 and A.2 in the appendix. (Batch size was such that not enough concrete was available to perform standard compression test). The specimens were cast and cured in accordance with the applicable requirements of ASTM C192. The specimens were removed from the forms 24 hours after casting and stored in saturated lime water for fourteen days prior to placement in the testing chamber. Specimens measured approximately 4 1/4 in. by 4 1/8 in. by 15 15/16 in.

Testing Equipment. A 18.2 cubic feet freeze thaw cabinet manufactured by Logan Refrigeration Co., Logan, Utah, Model No. ECAM-0075-1AA was used to perform the testing. Test specimens were placed in copper containers in the cabinet. Shims were used so that 1/8 in. of water covered the exterior sides of the specimens. Daily checking of water depth was made to insure a 1/8 in. water cover on top.

The chamber is completely automatic and was set such that the temperature of the specimens varied from $0^{o}F$ to $40^{o}F$ throughout the testing. Temperature was monitored by a probe placed inside a specimen identical in size to the test specimen but not part of the test program. The cabinet cycled approximately four times per day.

Sonometer instrumentation was used to determine the resonant frequency of the specimen as set forth in ASTM C666-77. The sonometer was composed of

Testing began on August 17, 1982 and was completed on November 12, 1982. Testing was never interrupted during the entire period.

TEST DATA

Dynamic Young's Modulus. Calculation of dynamic Young's modulus of elasticity, E, in pounds per square inch from the fundamental transverse frequency weight, and dimensions of the test specimen was done as follows:

$$\text{Dynamic } E = CWn^2$$

where:

w = weight of specimen, lb.
n = fundamental transverse frequency, Hz.
C = $0.00245\ (L^3T/bt^3)$, s^2/in^2 for a prism.
L = length of specimen, in.
t,b = dimensions of cross section of prism, in.
t being in the direction in which it is driven.
T = a correction factor which depends on the ratio of the radius of gyration, K, (for a prism K is t/3.464), to the length of the specimen, L, and Poisson's ratio. Values of T for Poisson's of 1/6 were obtained from Table 1 of ASTM C215.

Relative Dynamic Modulus of Elasticity. The calculations for the numerical values of relative dynamic modulus of elasticity were done as follows, (ASTM C666-77):

$$P_i = (n_i^2/n^2) \times 100$$

where:

P_i = relative dynamic modulus of elasticity after i cycles of freezing and thawing, percent.

n = fundamental transverse frequency at 0 cycles of freezing and thawing.

n_i = fundamental transverse frequency after i cycles of freezing and thawing.

Note: The calculation of relative dynamic modulus of elasticity is based on the assumption that the weight and dimensions of the specimen remain constant

throughout the test. This assumption is not true due to disintegration of the specimen in many cases. However, if the test is to be used to make comparisons between the relative dynamic moduli of different specimens or of different concrete formulations, the relative dynamic modulus of elasticity (P_i) as defined is adequate for the purpose.

Durability Factor. The calculation of the durability factor was performed as follows:

$$DF = \frac{PN}{M}$$

where:

DF = durability factor of the test specimen.

P = relative dynamic modulus of elasticity at N cycles, percent.

N = number of cycles at which p reaches the specified minimum value for discontinuing the test or the specified number of cycles at which the exposure is to be terminated, whichever is less.

M = specified number of cycles at which the exposure is to be terminated.

TEST RESULTS

The data obtained at the time of casting consists of slump and air content, shown in Table A.2. Test data taken before each cycle period consists of sample weight, sample dimensions and fundamental frequency. Weight and dimensions of specimens are shown in Table A.4 and measured frequencies in Tables A.5 and A.6.

Calculated data consists of the relative dynamic modulus of elasticity and durability factor and are shown inTables 1 and 2, respectively. The average relative dynamic modulus of elasticity results for specimens in each series are plotted against the number of freeze-thaw cycles as shown in Figure 1.

All specimens showed approximately the same amount of wear throughout the testing. The surfaces of the samples held the sample identification markings throughout the entire test period. At the end of 300 cycles all samples were still in tact and in relatively good condition.

Table 1
Average Relative Dynamic Modulus of Elasticity Values

Cycles	Relative Modulus of Elasticity* %	
	Series A	Series B
0	100	100
35	98.6	95.4
70	105.3	96.1
106	100.7	97.4
142	101.4	94.7
178	99.9	97.1
214	102.4	97.0
250	99.5	94.6
286	99.9	95.4
300	96.6	93.3

*Average of four specimens

Table 2
Durability Factors

Specimen Group	Durability Factor*, %
Series A	96.6
Series B	93.3

*Average of four specimens

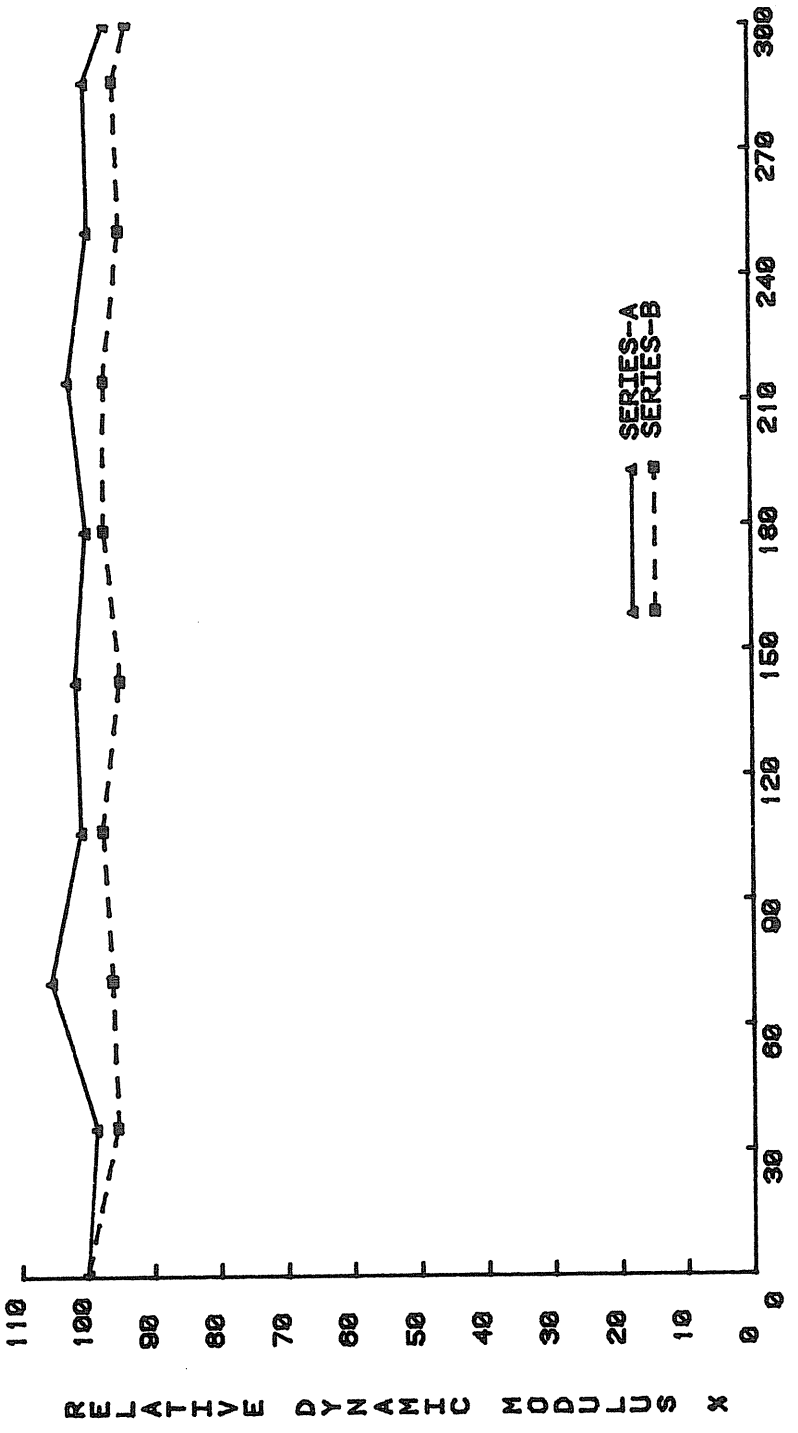

Figure 1. Relative Dynamic Modulus of Elasticity

APPENDIX A

TEST DATA

Table A.1

Materials

Material	Source
a) Type I Cement	Ideal Cement Company Ada, Oklahoma
b) Concrete Sand ASTM C-33	The Dolese Company Spencer, Oklahoma
c) Stone ASTM C-33 1½" #57	Dolese Bros. Company Davis, Oklahoma
d) Air Entraining Agent ASTM C-260	Protex Industries, Inc. Denver, Colorado

Table A.2

Mix Proportions per Cubic Yard

Cement:	564 lb
Sand :	1,226 lb (SSD)
Stone :	1,871 lb (SSD)
AEA :	6.0 oz
Water :	5" Slump

Table A.3

Batch Test Data

Specimen Group	Slump (in)	Air Content (%)
Series A	5½	5½
Series B	5¼	6¼

Table A.4

Specimen Data

Specimen No.	Length (in)	Heighth (in)	Width (in)	Initial Lot
A1	15.938	4.30	4.178	23.3
A2	15.938	4.319	4.181	23.4
A3	15.938	4.280	4.172	23.2
A4	15.938	4.29	4.135	23.0
B1	15.938	4.3.1	4.172	23.4
B2	15.938	4.262	4.118	22.6
B3	15.938	4.319	4.157	23.2
B4	15.938	4.308	4.177	23.4

Table A.5
Frequency Related Data, Series - A

OF CYCLES = 0

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2195.00	23.40	5095928.7	100.0
2	2123.00	23.30	4767731.2	100.0
3	2226.00	23.20	5265065.6	100.0
4	2212.00	23.00	5255511.2	100.0

OF CYCLES = 35

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2167.00	23.30	4978346.7	97.5
2	2125.00	23.30	4787239.8	100.2
3	2215.00	23.20	5213158.4	99.0
4	2188.00	23.00	5142086.2	97.8

OF CYCLES = 70

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2315.00	23.30	5669095.4	111.2
2	2203.00	23.30	5156437.5	107.7
3	2185.00	23.10	5084119.9	96.4
4	2277.00	23.00	5533142.8	106.0

OF CYCLES = 106

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2201.00	23.10	5069326.5	100.5
2	2232.00	22.90	5213628.3	110.5
3	2152.00	22.80	4846543.0	93.5
4	2192.00	22.80	5105071.9	98.2

OF CYCLES = 142

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2200.00	22.80	5021016.0	100.5
2	2180.00	22.60	4951335.5	105.4
3	2220.00	22.50	5078716.2	99.5
4	2215.00	22.70	5123080.1	100.3

Table A.5
Frequency Related Data - Series A, (Cont.)

OF CYCLES = 178

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2198.00	22.40	5021360.2	100.3
2	2130.00	22.55	4767510.6	100.7
3	2220.00	22.50	5111982.9	99.5
4	2201.00	22.60	5189516.1	99.0

OF CYCLES = 214

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2238.00	22.40	5239442.3	104.0
2	2189.00	22.35	5012044.3	106.3
3	2218.00	22.25	5100808.5	99.3
4	2211.00	22.30	5243574.3	99.9

OF CYCLES = 250

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2165.00	22.10	4878979.4	97.3
2	2164.00	22.00	4831812.1	103.9
3	2208.00	22.00	5094650.9	98.4
4	2193.00	22.00	5089147.3	98.3

OF CYCLES = 286

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2187.00	21.80	4994471.9	99.3
2	2155.00	21.70	4827138.9	103.0
3	2202.00	21.70	5082080.0	97.9
4	2203.00	21.70	5107759.8	99.2

OF CYCLES = 300

SAMPLE SERIES A	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2148.00	21.80	4848105.8	95.8
2	2084.00	21.70	4552000.4	96.4
3	2185.00	21.60	5022102.8	96.4
4	2189.00	21.70	5053444.8	97.9

Table A.6
Frequency Related Data, Series - B

OF CYCLES = 0

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2190.00	23.40	5106407.7	100.0
2	2190.00	22.60	5148613.4	100.0
3	2320.00	23.20	5719122.9	100.0
4	2222.00	23.40	5245173.0	100.0

OF CYCLES = 35

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2191.00	23.40	5156004.6	100.1
2	2157.00	22.60	5047193.6	97.0
3	2163.00	23.20	4971260.3	86.9
4	2196.00	23.40	5123141.9	97.7

OF CYCLES = 70

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2172.00	23.40	5011772.5	98.4
2	2205.00	22.60	5241360.2	101.4
3	2152.00	23.20	4931570.0	86.0
4	2207.00	23.40	5163197.4	98.7

OF CYCLES = 106

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2235.00	23.20	5261370.6	104.2
2	2189.00	22.20	5031594.6	99.9
3	2148.00	22.80	4796983.7	85.7
4	2231.00	23.10	5196962.2	100.8

OF CYCLES = 142

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2210.00	23.00	5099977.2	101.8
2	1994.00	22.00	4198694.0	82.9
3	2230.00	22.60	5136110.6	92.4
4	2239.00	22.80	5223471.6	101.5

Table A.6
Frequency Related Data, Series - B, (Cont.)

OF CYCLES = 178

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2193.00	22.80	5043940.4	100.3
2	2160.00	22.00	4926873.6	97.3
3	2217.00	22.60	5154158.9	91.3
4	2218.00	22.80	5226895.9	99.6

OF CYCLES = 214

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2213.00	22.40	5134009.9	102.1
2	2179.00	21.60	5045838.1	99.0
3	2194.00	22.40	5078578.5	89.4
4	2193.00	22.50	5053318.4	97.4

OF CYCLES = 250

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2180.00	22.30	4959794.7	99.1
2	2171.00	21.30	4939288.0	98.3
3	2159.00	22.00	4901803.1	86.6
4	2158.00	22.30	4880964.0	94.3

OF CYCLES = 286

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2190.00	22.00	5054130.2	100.0
2	2144.00	21.10	4723468.0	95.8
3	2173.00	21.70	4897868.1	87.7
4	2199.00	22.00	5063841.4	97.9

OF CYCLES = 300

SAMPLE SERIES B	FREQUENCY hz	WEIGHT lbs	DYNE lbs/in^2	REL E %
1	2180.00	21.90	4985315.1	99.1
2	2143.00	21.00	4754562.4	95.8
3	2195.00	21.60	5005735.3	89.5
4	2094.00	21.90	4570928.4	88.8