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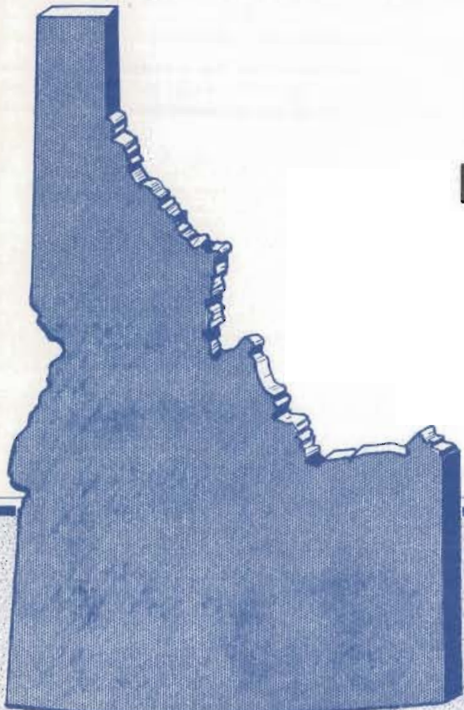
EFFECTS OF ALUMINUM PIPE ON PUMPED CONCRETE



DECEMBER 1969

RESEARCH PROJECT NO. 55

STATE OF IDAHO DEPARTMENT OF HIGHWAYS

EFFECTS OF ALUMINUM PIPE ON PUMPED CONCRETE

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INTRODUCTION

On May 26, 27 and 28, 1969 a deck slab was placed using a concrete mix with higher than specification slump and in which some lumps of sand and cement were observed. Consequently the strength of the concrete was questioned. Cores were cut from the bridge deck and tested for compressive strength. The test results indicated lower strengths on two spans. Retests with additional cores taken from these two spans confirmed the original test results. It was decided that the strengths were so low that the replacement of one span was required.

During a recent visit to the Department a Highway Research Board Engineer was informed of this situation. He was told that the concrete had been placed by pumping. He advised us that if the concrete had been pumped through aluminum pipe This could be the cause of the low strengths, and told of a similar situation where strength losses of 40-50 percent had resulted from the use of aluminum pipe in pumping concrete.

Telephone contact was immediately made with the principal investigator of the earlier situation. We were convinced that our situation was parallel and that the strength loss of concrete in our bridge deck could probably be attributed to pumping through aluminum pipe.

It was decided that a test was necessary to assure us that the strength loss actually could be attributed to pumping through aluminum pipe.

CONCLUSIONS

The analysis of the strength data, when correlated with the length of aluminum pipe line used to place the concrete on projects F-6354(4), F-6807(1), and the experiment at Challis, indicates that the abraded aluminum from the pipe line is the cause of the strength loss.

RECOMMENDATIONS

1. Aluminum pipe be prohibited from use in transporting pumped concrete. No restriction be placed on the use of steel pipe or rubber hose.

2. That hereafter all tests of concrete placed by pumping be conducted at the end of the pipe line as the concrete is placed. This includes slump, air content and manufacture of all cylinders.

3. That the standard specifications for concrete be modified immediately as follows:

Section 502.07 Equipment

Add a paragraph (d) as follows:

The equipment used shall provide concrete at the point of placement meeting all specifications requirements for concrete,slump, air content and intended strength. Aluminum pipe shall not be used in pumping concrete.

INVESTIGATION

The investigation consisted of placing a seven inch concrete slab on the ground adjacent to the maintenance building at Challis. Concrete was manufactured using the same cement, aggregate, air entraining agent and water reducer in the proportions reported to have been used on the project. Since an error was discovered in the scale weights used on the bridge,resulting in 1,100 lbs. more sand in the six cubic yard batch than intended, a batch was prepared using these proportions also. Mix No. 5 is designated the standard mix and Mix No. 5A the over sanded mix. Table I gives the weights used to make up a one cubic yard batch. Table II gives the range of air content and slump of the batches placed in the Challis maintenance building slab.

TABLE I

CONCRETE MIX BATCH WEIGHTS/C.Y.
CHALLIS MAINTENANCE BUILDING SLAB

	Mix 5	Mix 5A
Cement, lbs.	597	597
Water, gals.	31.2+3.33 Added	31.1+1.67
Sand, lbs.	1303	1464
Gravel, lbs.	1539	1539
Air, Protex, oz.	6	6
Water Reducer PDA, oz.	26	26

3.33 Gals. additional water added to Mix 5 at Placement.

1.67 Gals. additional water added to Mix 5A at Placement

TABLE II

FIELD TESTS ON CONCRETE

	Mix 5	Mix 5A
Slump, ins.	7 8	2-1/2 3-1/2
Air Content	4.2 4.2	3-1/2 4.3

The concrete test slab was placed September 30, 1969 on a clear, cool day. The maximum temperature during the day was 69°F. and the minimum was 47°F. Curing temperatures during the period before removing cores ranged from a low of 11°F. to a high of 72°F. Near freezing night time temperatures generally prevailed after October 3 with temperatures from 5° to 20° below freezing at night after the 10th of October. Cores were placed under water in the Central Lab on October 16 and cured out of doors in the shade until the day before testing. Temperatures generally ranged from lows of about 40°F. to highs of about 75°-80°F. Admittedly these differences in curing temperatures did effect strengths. The trend indicating the effect of abraded aluminum was still found to exist.

Table III shows the results of strength tests at 29 days age for the 6"x12" cylinders and 2-3/4" diameter x 5-1/2" high cores. It is evident in both instances that strength was lost due to pumping through the aluminum pipe. It appears that greater strength losses occured in the slab than in the cylinders which may be due to variations in compaction by vibration.

Twenty five cores were taken at various times from the structure of project f-6354(4). Figure 2 is a plot of strength test results against length of aluminum pipe used to place concrete, using centerline distances only. Actual length could differ slightly since a short section of rubber hose was used at the end of the aluminum pipe and exact placement of the pump is unknown. The solid line indicates a strength loss trend very similar to the loss experienced in the Challis experiment.

Cores were submitted to the Portland Cement Association Laboratories for air-voids determinations and freeze-thaw tests. Air void determinations were made according to ASTM C-457-67T "The Microscopical Determination of Air Void Content, Specific Surface and Spacing Factor of the Air Void System in Hardened Concrete". One specimen of concrete contained 15.3% air and 16 voids per linear inch of traverse and the other contained 10.0% air and 9 voids per linear inch of traverse.

TABLE III

29-DAY COMPRESSIVE STRENGTHS
CHALLIS MAINTENANCE BUILDING SLAB

	6 x 12 Cyls.		Cores	
	Mix 5	Mix 5A	Mix 5	Mix 5A
Truck Placed	3180	3160	3070	2750
Pumped 150 Feet	2920	2890	2320	2260
Pumped 250 Feet	2810	2570	2250	2130

Cylinders were removed to Boise on third day and cured out of doors in shade until day before testing.

Cores were removed from the slab at 2 weeks age, removed to Central Lab. and cured under water until tested. Cores were 7 inches long but cut back to 5 1/2 inches for h/d of 2.0.

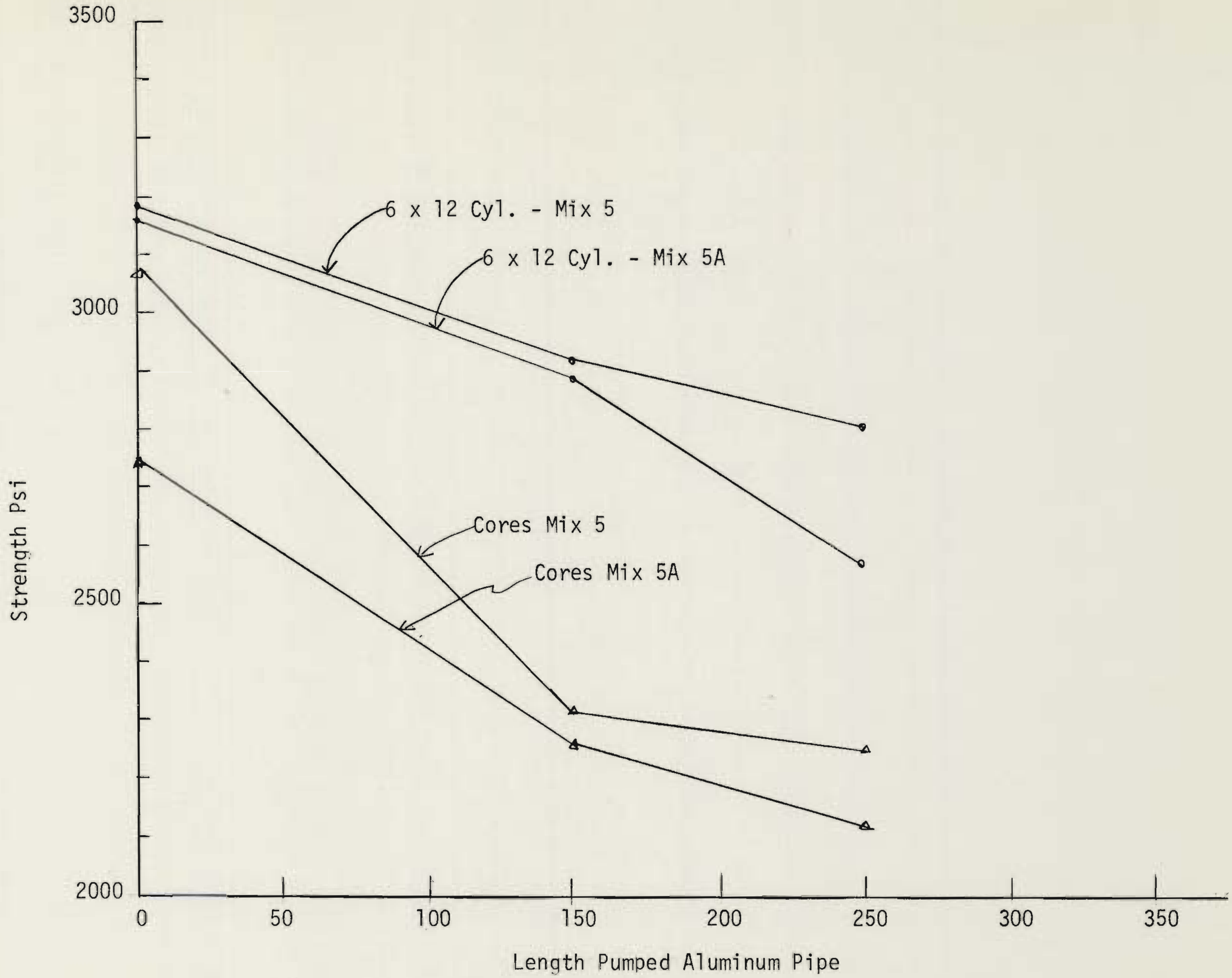

Figure 1 - Strengths Obtained from Concrete Placed-Challis Maint. Bldg.

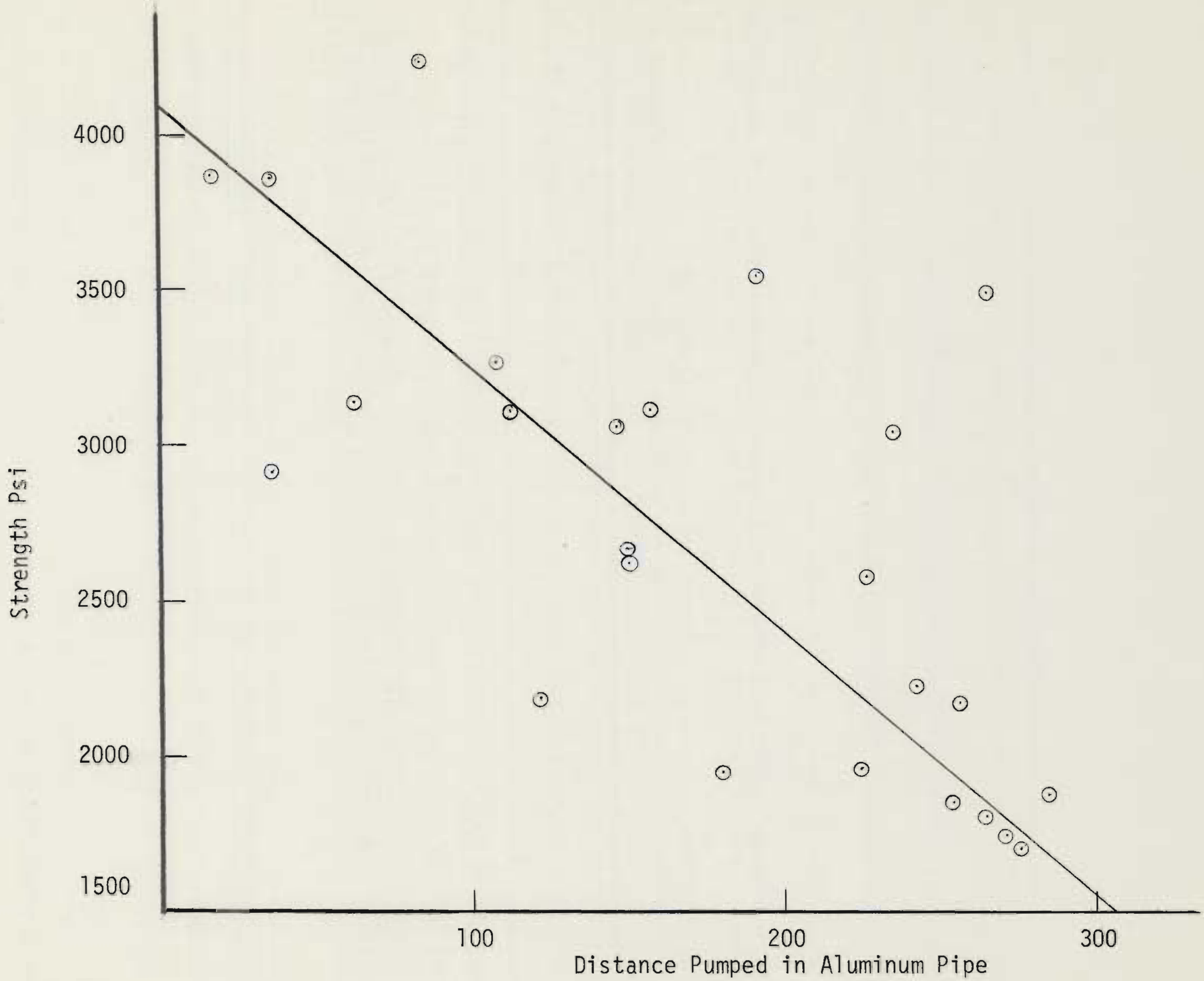

Figure 2 - Strengths Obtained on Concrete Cores Removed from Bridge Deck Project F-6354(4)

Specifications provided for six plus/minus 1-1/2% air in the concrete. Gas formation as described later in the report could account for this added amount of air. Twenty four cycles of freeze and thaw had caused little damage to the concrete. Further freeze-thaw tests were planned.

Nine cores were also taken for project S-6807(1). Concrete was pumped from both ends on this structure using a combination of aluminum pipe and rubber hose. Here again lowest strengths were obtained where the longest aluminum pipe was used. Figure 3 shows these results.

Laboratory efforts to duplicate the concrete mixture used on project F-6354(4), including all ingredients, even water, resulted in concrete meeting strength requirements even though the slump was outside specifications. Curing was in the laboratory moist room giving some advantage to these cylinders. Comparable results were obtained from job made cylinders which were formed at the concrete pump rather than at the end of the pipe line. Table IV shows these results.

NATURE OF THE REACTION

Aluminum, zinc and magnesium have all been known and used as gas forming admixtures for concrete. Only aluminum has received extensive use. The A. C. I. Manual of Concrete Practice reports that amounts added are usually in the range of 0.005 to 0.02 percent by weight of the cement. Its use is particularly useful in grouting under machinery, etc. due to the slight expansion due to the gas formation. It is this gas formation which is responsible for strength loss just as air entraining also causes loss of strength. The creation of gas in excess of that needed for air entrainment is responsible for the excessive strength loss.

The quantity of aluminum required as a gas forming additive is only from 2 to 8.5 grams per sack of cement. Each cubic foot of concrete passing through a four inch pipe line would have to abrade from the side walls from 0.45 to 1.9 gms. of aluminum. It takes 11.5 feet of four inch line to hold one cubic foot or the area abraded by one cubic foot would be 1725 sq. ft. for 150 feet of line and

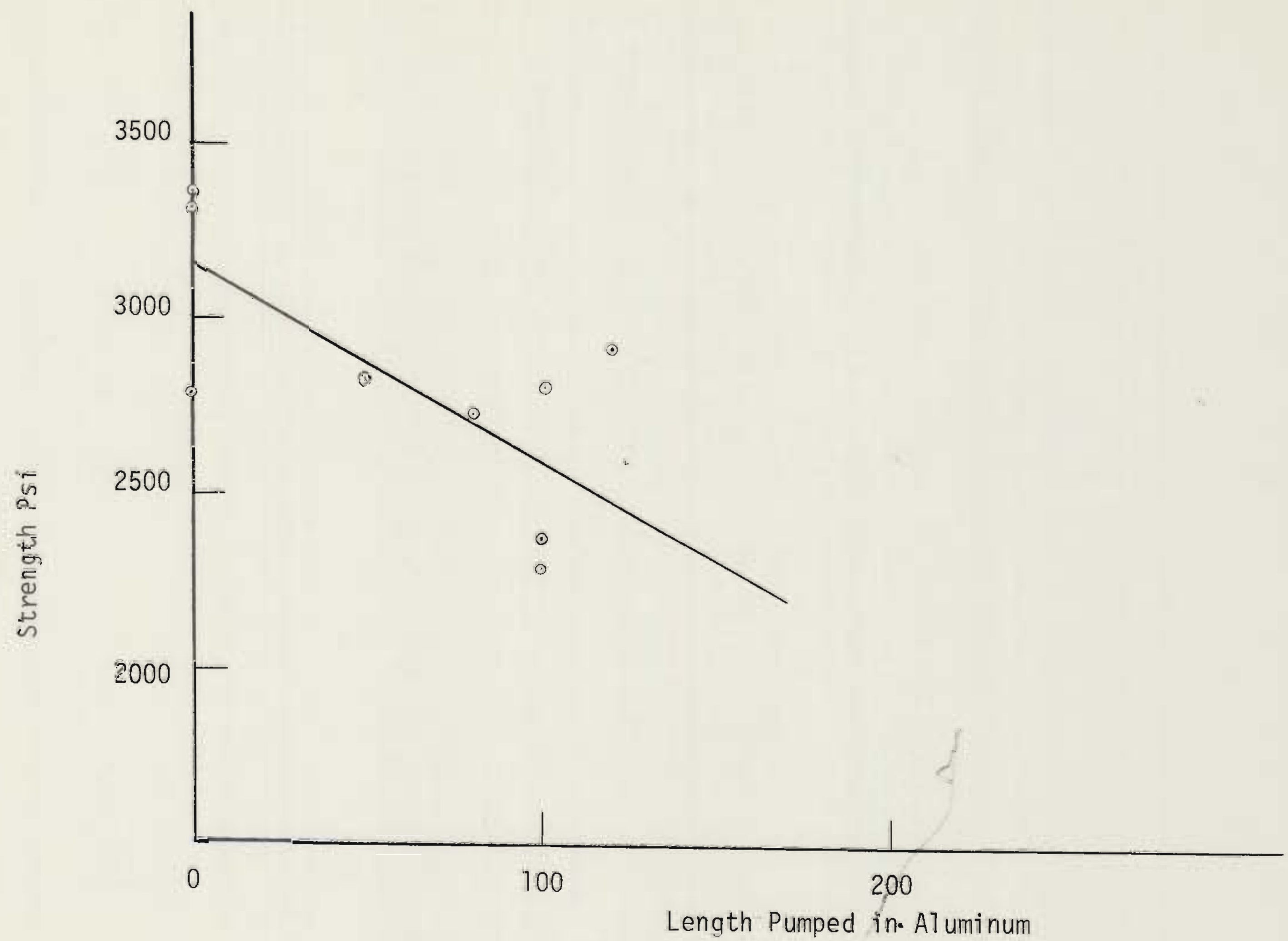

Figure 3 - Strengths Obtained on Concrete Cores Removed from Bridge Deck
Project S-6807(1)

TABLE IV

CONCRETE DECK CYLINDER STRENGTHS

Field Tests Ave. of 3	May 26 - 3287 27 - 4563 28 - 3903 29 - 4357	See Table I for proportions		
	Laboratory Trial Mix Duplication of Field Mix Above Including all Ingredients			
	Trial No. 1		Trial No. 2	
Mix 5	7 day	28 day	7 day	28 day
	3330 psi	4050 psi	3490 psi	4670 psi
	Slump 8 in. Air 4.8%		Slump 7 in. Air 5.2%	
Mix 5A Over sanded	3000 psi	3960 psi	3020 psi	4330 psi
	Slump 7 1/2" Air 5.2%		Slump 8" Air 5.5%	

2880 sq. ft. for 250 feet of line. It is evident the loss of aluminum is low.

The reaction is between the aluminum and hydroxides in the cement forming hydrogen gas. The rate and extent of reaction will depend on the type and amount of aluminum, its fineness, the composition of the cement, temperature, mixture proportions and other possible factors, i.e. harshness of mix, slump, etc. At normal temperatures such as occurred in May the reaction will continue for 1-1/2 to 4 hours. At temperatures around 40°F. it may require twice the aluminum to produce the same reaction as at 70°F.

APPENDIX

TABLE V - STRENGTHS OBTAINED FROM CONCRETE PLACED-CHALLIS MAINTENANCE BUILDING

MIX #5, DIRECT FROM TRUCK

Cylinder Ident. No.	29 Day Tests Comp. Strength	Core Ident. No.	29 Day Tests Comp. Strength
1026-CX	3330	1111-CX	3030
1027-CX	3180	1112-CX	3000
1028-CX	3180	1113-CX	3080
1029-CX	3150	1114-CX	3250
1030-CX	3040	1115-CX	3010
Average	3180	Average	3070

MIX #5, PUMPED THROUGH 150' ALUMINUM LINE

Cylinder Ident. No.	29 Day Tests Comp. Strength	Core Ident. No.	29 Day Tests Comp. Strength
1016-CX	3000	1106-CX	2390
1017-CX	3000	1107-CX	2220
1018-CX	3000	1108-CX	2360
1019-CX	2790	1109-CX	2290
1020-CX	2830	1110-CX	2320
Average	2920	Average	2320

MIX #5, PUMPED THROUGH 250' ALUMINUM LINE

Cylinder Ident. No.	29 Day Tests Comp. Strength	Core Ident. No.	29 Day Tests Comp. Strength
1006-CX	2940	1101-CX	2220
1007-CX	2720	1102-CX	2360
1008-CX	2790	1103-CX	2360
1009-CX	2870	1104-CX	2070
1010-CX	2720	1105-CX	2220
Average	2810	Average	2250

TABLE VI - STRENGTHS OBTAINED ON CONCRETE CORES REMOVED FROM BRIDGE DECK PROJECT F-6354(4)

Core No.	Lab. No.	Location	Length Pumped	Compressive Strength Psi	Age at Testing Days
1	233022	25' From N. end 5'6" from curb-NBL	35	3880	29
2	233022	141' from S. end 8'4-1/2" from center	150	2670	30
3	233022	141'6" from S. end 10' from curb-SBL	150	2630	30
4	233022	25' from N. end 5'6" from curb-SBL	35	2910	29
5	233022	15' from s. end 5'9" from curb-SBL	276	1710	30
6	233022	25' from S. end 5'9-1/2" from curb-NBL	266	1820	30
7	234500	Sta. 253+01	159	3140	66
8	234501	Sta. 253+13-8'4" RT	147	3090	66
9	234502	Sta. 251+93-1315" RT	266	3500	66
10	234503	Sta. 251+86-14' RT	274	1720	66
11	234504	Sta. 252+17-11' RT	243	2220	66
12	234505	Sta. 252+24-4' LT	236	3070	66
13	*2576	Sta. 251+75-10.4' RT	285	2380	95
14	*2577	Sta. 251+75-13.8' LT	285	1160	95
15	*2578	Sta. 252+07-4' LT	253	2690	95
16	*2579	Sta. 252+06-13' LT	253	2370	95
17	*2580	Sta. 252+36-15' LT	224	1970	95
18	*2581	Sta. 252+31-11' RT	229	2580	95
19	*2582	Sta. 252+81-10' RT	179	1940	95
20	*2583	Sta. 253+38-15' LT	122	2190	95
21	238439	Sta. 252+66-12' LT	194	3550	113
22	238440	Sta. 252+47-8' RT	113	3120	113
23	238441	Sta. 253+52-9' RT	108	3280	112
24	238442	Sta. 253+75-1'6" LT	85	4230	112
25	238443	Sta. 254+42-7' LT	18	3870	113
26	238444	Sta. 253+99-11' RT	61	3140	113
		Pump Approx. 254+60			

*Northern Testing Laboratory, Boise