

II

*AVILES ENGINEERING TESTING OF XYPEX
AND
PLAIN REFERENCE CONCRETE IN SULFURIC ACID*

AVILES ENGINEERING CORPORATION (TEXAS)

SULFURIC ACID RESISTANCE AND PERMEABILITY TESTS

* Sulfuric Acid Resistance Test was performed to determine corrosion resistance of Concentrate Admix treated concrete

* the word "Catalyst" used in this report is the equivalent of "Xypex Concentrate Admix"

* acid resistance measured weight loss as the factor used to determine degree of corrosion resistance, variations in admix dosages resulted in a range of effectiveness

* 19 / 25 / 40 / 139 day cures refer to the number of days that elapsed from the time the concrete sample was cast to the day acid testing was initiated



8 February 1993

Mr. D'Arcy Mainwaring
Xypex Chemical Company
13731 Mayfield Place
Richmond, B.C.
Canada V6V 2G9

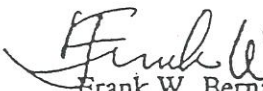
Re: 7% H₂SO₄ Solution - Xypex Catalyst Admix Concrete Study

We have completed the laboratory testing program outlined by Mr. Bill Golden to study the effects of Sulfuric Acid on concrete samples. All concrete samples were obtained by Hydro Conduit Corporation personnel and delivered to Aviles Engineering Corporation's (AEC) laboratory for this test program.

Samples received at AEC's laboratory were of various shapes and sizes that required AEC to cut these samples to a size suitable for immersion in the sulfuric acid solution. As instructed by Mr. Golden, after immersion, all sample containers were kept in controlled curing room at 100% humidity and 73° F +/- 3° F temperature. The weight loss on each sample was weighed and recorded on a daily basis until a weight loss of 50% or a definite response trend was obtained.

Attached are all the laboratory data sheets obtained during this testing program.

Should you have any questions, or need any additional information, please feel free to contact us.


Frank W. Bernacki, P.E.
Executive Vice President



FWB:lm

Attachment

Copies to: Concrete Solidification Tech (1)
File (1)

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SAMPLE IDENTIFICATION

SAMPLE NO. A.E.C.	H.C.C. IDENTIFICATION	SULFURIC ACID SOLUTION
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19 Days Age

1	Ref. Control - Standard Mix	7%
2	Ref. B - 5% Catalyst	7%
3	Ref. C - 7% Catalyst	7%

25 Days Age

4	Ref. Control - Standard Mix	7%
5	Ref. C - 7% Catalyst	7%
6	Ref. D - 5% Catalyst	7%

139 Days Age

7	Ref. D - 5% Catalyst	7%
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40 Days Age

8	Ref. Control - Standard Mix	7%
9	Ref. A - 3% Catalyst	7%
10	Ref. B - 5% Catalyst	7%
11	Ref. C - 7% Catalyst	7%
12	Ref. D - 5% Catalyst	7%

40 Day Cure

Test C - Percent of Weight Loss In Days

DAYS	CONTROL	ADMIX "A"	ADMIX "B"	ADMIX "C"	ADMIX "D"	139 Day
0	0	0	0	0	0	0
1	0.95	0.57	0.42	0.5	0.29	0
2	3.66	2.49	2.16	2.26	1.71	0.63
3	5.45	3.85	3.41	3.74	2.63	0.9
4	7.82	5.65	5.27	5.53	3.93	2.41
5	9.82	7.5	7.13	7.32	5.26	3.31
6	11.66	9.25	8.99	9.11	6.63	4.2
7	14	11.88	11.23	11.95	8.26	5.1
8	15.94	13.89	13.5	14.18	9.96	5.1
9	18.66	15.7	15.01	15.97	11.74	5.6
10	21.38	17.5	16.52	17.76	13.73	5.6
11	24.1	19.31	18.03	19.55	15.61	6.02
12	26.81	21.11	19.54	21.34	17.5	6.18
13	29.53	22.92	21.05	23.14	19.38	6.33
14	32.25	24.72	22.56	24.93	21.27	6.49
15	34.97	26.53	24.07	26.72	23.15	8.12
16	37.33	28.33	25.58	28.51	24.69	8.56
17	39.4	30.14	27.09	30.3	26.24	9
18	42.06	31.95	28.6	32.09	27.78	9.44
19	44.42	33.75	30.11	33.88	29.32	9.88
20	46.78	35.56	31.62	35.67	30.86	10.32
21	49.15	37.36	33.13	37.46	32.41	10.76
22	51.5	39.17	34.64	39.25	33.95	11.11
23	53.87	40.97	36.15	41.05	35.49	11.45
24		42.78	37.66	42.84	36.46	11.8
25		44.58	39.17	44.63	37.43	12.15
26		46.39	40.68	46.42	38.4	12.49
27		48.19	42.19	48.2	39.37	12.84
28		50	43.7	50	40.34	13.19
29						13.54
30						13.88

25 Day Cure

Test B - Percent of weight loss in Days

Days	Control	Admix "C"	Admix "D"	139 Day
0	0	0	0	0
1	1.07	0.71	0.74	0
2	3.3	2.47	2.56	0.63
3	5.05	4.1	4.04	0.9
4	7.48	6.2	6.28	2.41
5	10.4	7.84	7.97	3.31
6	12.95	9.48	9.66	4.2
7	13.37	11.13	11.35	5.1
8	15.18	12.7	12.61	5.1
9	17.31	14.9	14.61	5.6
10	19.13	16.2	16.15	5.6
11	21.63	18.23	18.3	6.02
12	23.58	19.7	19.84	6.18
13	25.53	21.13	21.38	6.33
14	27.49	22.65	22.92	6.49
15	29.9	24.86	25.57	8.12
16	31.85	26.34	27.36	8.56
17	33.8	27.82	29.15	9
18	35.75	29.3	30.94	9.44
19	37.7	30.78	32.73	9.88
20	39.65	32.26	34.52	10.32
21	41.65	33.75	36.32	10.76
22	43.13	34.82	37.52	11.11
23	44.61	35.88	38.72	11.45
24	46.09	36.95	39.92	11.8
25	47.57	38.02	41.12	12.15
26	49.04	39.09	42.32	12.49
27	50.52	40.15	43.52	12.84
28	52	41.22	44.72	13.19
29	53.48	42.29	45.92	13.54
30	54.96	43.35	47.12	13.88
31	56.44	44.42	48.32	14.23
32		45.39	49.05	14.72
33		46.37	49.78	15.2
34		47.34	-50.5	15.69
35		48.31	51.23	16.18
36		49.28	51.96	16.66
37		-50.26	52.69	17.15
38		51.23	53.41	17.63
39		52.2	54.14	18.12
40				18.18
41				18.24



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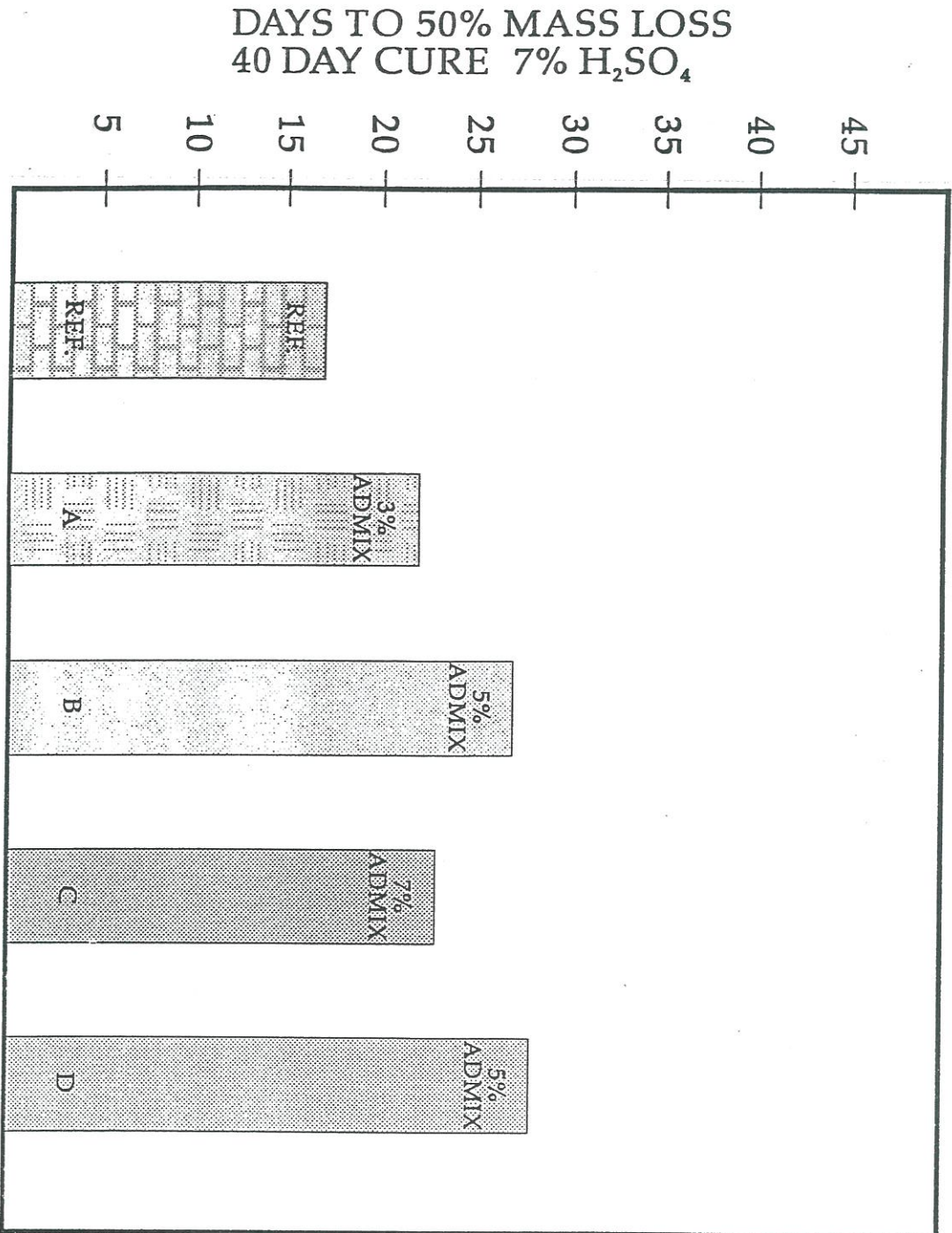
42	18.3
43	18.36
44	18.42

19 Day Cure

Test A - Percent of weight loss In Days

Days	Control	Mix"B"	Mix"C"
0	0	0	0
1	0.88	1.08	0.097
2	2.07	2.52	2.41
3	3.74	4.33	4.09
4	4.9	5.56	5.25
5	6.06	6.79	6.41
6	7.22	8.02	7.56
7	8.38	9.25	8.72
8	10	10.98	10.42
9	11.93	12.89	12.48
10	13.44	14.64	14.2
11	15.94	16.99	16.76

TEST #2 - AVILES ENGINEERING - XYPEX ADMIX IN 7% SULPHURIC ACID



MIX DESIGN REF, A, B, C

CEMENT - 482 LBS
FLY ASH - 161 LBS
SAND - 1955 LBS
ROCK - 2120 LBS
SLUMP - 0"

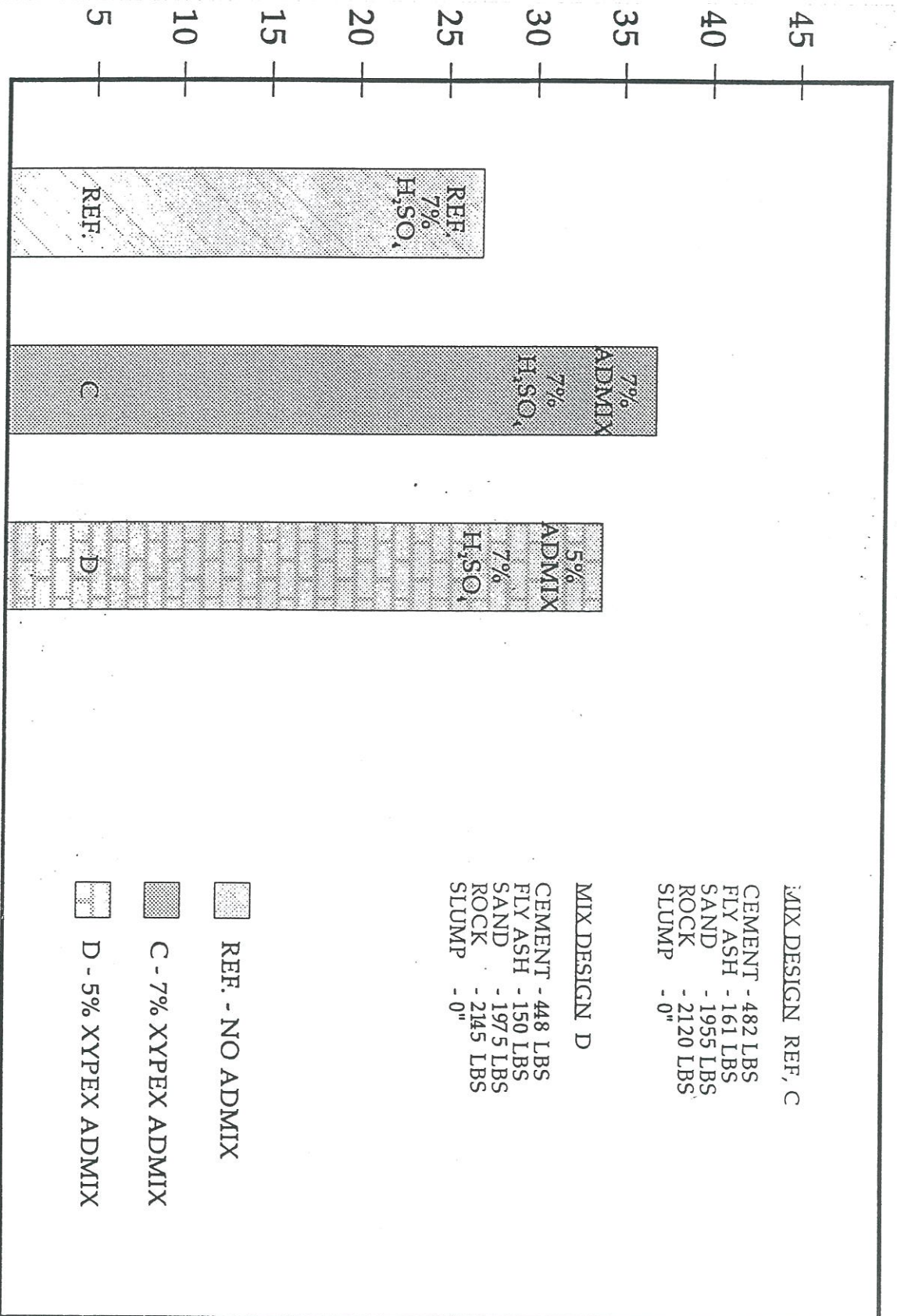
MIX DESIGN D

CEMENT - 448 LBS
FLY ASH - 150 LBS
SAND - 1975 LBS
ROCK - 2145 LBS
SLUMP - 0"

- REF. - NO ADMIX
- A - 3% XYPEX ADMIX
- B - 5% XYPEX ADMIX
- C - 7% XYPEX ADMIX
- D - 5% XYPEX ADMIX

TEST #2 - AVILES ENGINEERING - XYPEX ADMIX IN 7% SULPHURIC ACID

DAYS TO 50% MASS LOSS
25 DAY CURE 7% H₂SO₄



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Procedures:

Acid tests were conducted on the following concrete samples:

Test A. Standard Wet Cast Concrete

1. 28 day f'c minimum compressive strength = 3000psi.
2. 5% H_2SO_4 with constant pH = 0.7.
3. Concrete age at start of test = 67 days.

At the end of every 24 hour period, each sample was rinsed with water and weighed.

After weighing and recording the new weight, the sample was returned to the H_2SO_4 acid solution.

After return of the sample to the solution, the solution was checked and recharged to maintain a pH of .7

Specimens for Test "A" were obtained from a standard concrete mix. (Specimen I) and concrete with XYPEX admixture quantities of 13 lbs/cu yd (Specimen II) and 33 lbs/cu yd (Specimen III). Sixty-seven (67) day old specimens were selected in order to insure absence of free moisture within the concrete and to insure growth and development of fully mature dendritic crystalline and the resultant protective crystalline matrix. Unlike actual acid conditions encountered within a sanitary sewer, this test determined the relative acid resistance under constant acid conditions. This concrete is representative of that normally encountered in manholes, structures, etc.

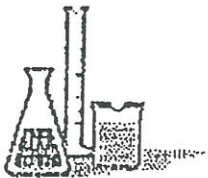
Test "B" Zero slump concrete and wet cast concrete

1. 28 day f'c minimum compressive strength = 4000 psi
2. 7% H_2SO_4 acid with constant solution volume with variable pH as the sample is attacked and acid is diluted.
3. Concrete age at start of test
 - a. Control & Specimen IV = 19 days
 - b. Control & Specimen V = 25 days
 - c. Control & Specimen VI = 40 days
 - d. Control & Specimen VII = 139 days

Age of concrete to be tested was selected to provide the following information:

1. Negative effects relative to acid resistance during the early curing process (19 days old)
2. Confirmation of crystalline initiation and growth during the fourth week of cure (25 days old)
3. Continued development of acid resistance after 28 days while still curing and with internal moisture present (40 days old)
4. Comparison to fully cured concrete of similar mix design (139 days old).

Comparison evaluation and testing was continued for each concrete age until a definite trend was established and/or the solution pH had changed significantly enough between samples being tested to distort the evaluation results.

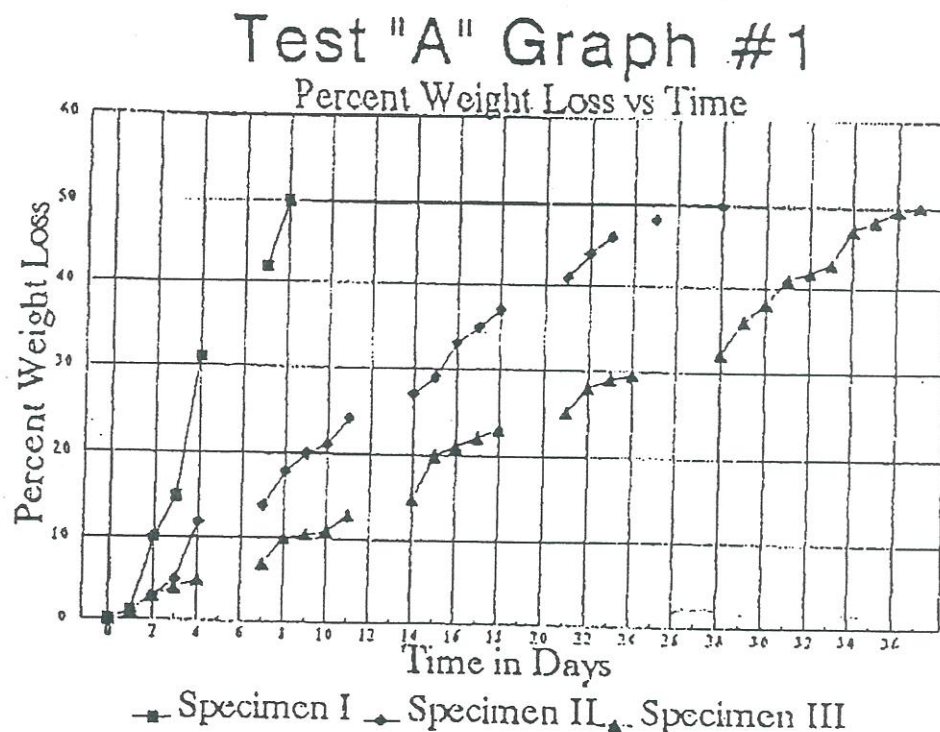


Concrete samples for Specimens IV, V, VI were obtained from pipe manufactured by ~~XXXXXXXXXX~~ with granitic aggregate concrete and pipe manufactured by ~~XXXXXXXXXX~~ with limestone aggregate concrete. All tests were conducted by ~~XXXXXX~~ Engineering located in Houston, Texas.

Specimen VII was selected because of age to insure full growth of the crystalline structure. These samples were manufactured using a wetcast process with approximately the same proportions as the concrete mix for the pipe.

Test "B" approximates the severe conditions that would actually be encountered within a sanitary sewer.

Test "A" Results:



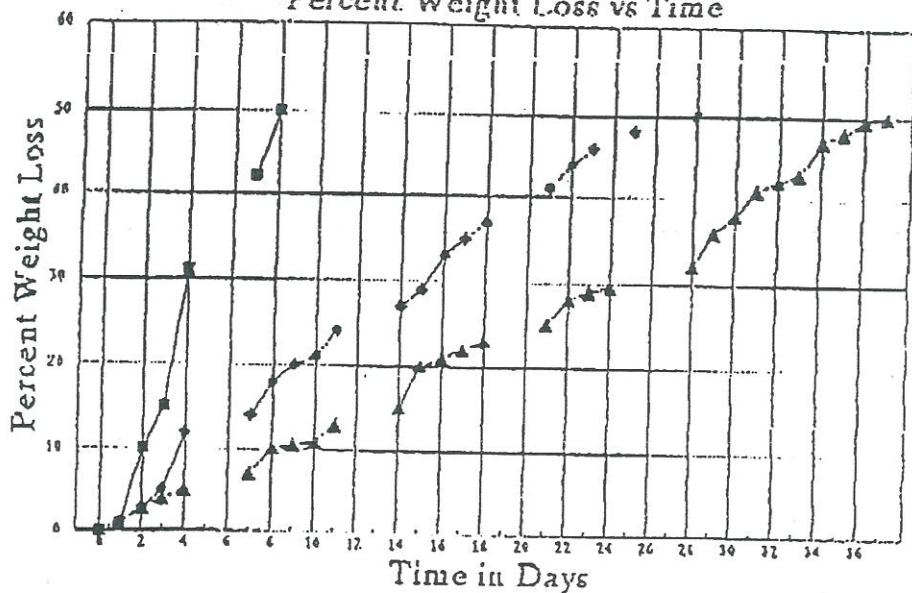
As shown on Test "A" Graph #1, the weigh periods along with correspondent weight loss produce a generally linear deterioration of the control sample, as do the weigh periods and weight loss recorded for the admix samples.

It should be noted that compressive strength comparisons and permeability comparisons were made utilizing samples from the same concrete casting to afford simultaneous tracking of multiple characteristics of concrete with admix added and the general relationship of the characteristics.

	<u>Acid Resistance</u>	<u>28 day f'c</u>	<u>Permeability/Absorption</u>
Control	1.01:1	3860psi	Full Flow @ 40' head
13 lbs	3.375:1	4350psi	Impervious @ 400' head
33 lbs	4.625:1	4460psi	Impervious @ 400' head

Test "A" Graph #1

Percent Weight Loss vs Time

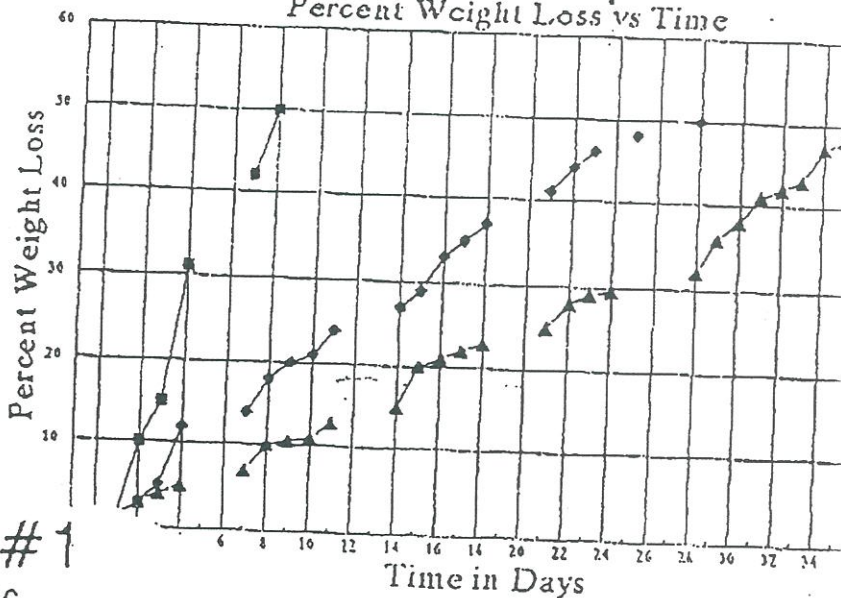


■ Specimen I ◆ Specimen II ▲ Specimen III

D'ARCY
There are
new
Graphs
I will FAX
LATER

Test "A" Graph #1

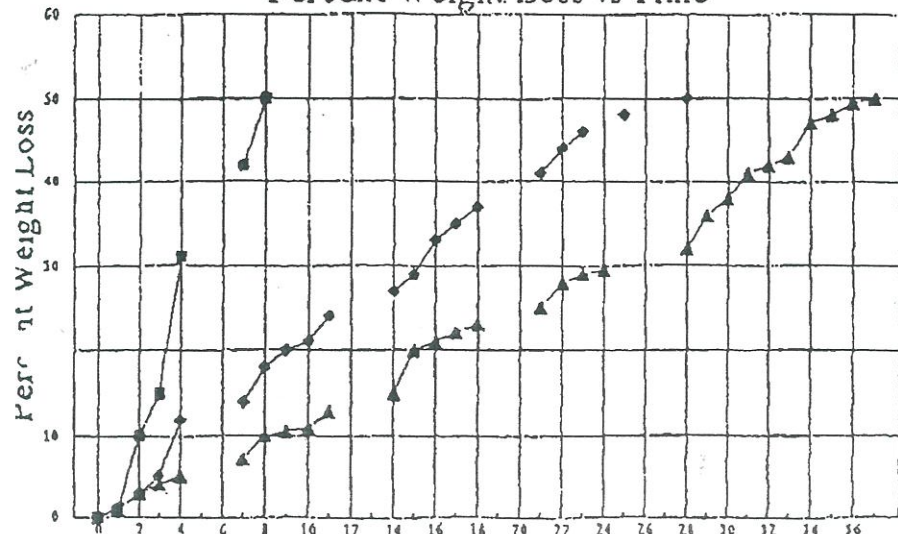
Percent Weight Loss vs Time



men I ◆ Specimen II ▲ Specimen III

Test "A" Graph #1

Percent Weight Loss vs Time



(THREE GRAPHS HERE)

Test cylinders and cores were prepared for comparative compressive strengths to be determined at specific time intervals after casting. Time intervals selected were 1 day, 4 days, 7 days, and 28 days. Mix proportions produce approximately 2.1 cu yd batches.

Item	Reference	Admixture A	Admixture B	Admixture C	Admixture D
Specimen		V	VI	VII	VIII
Cement-lbs	402	402	402	402	373
Fly Ash-lbs	134	134	134	134	124
C Agg-lbs	1629	1629	1629	1629	1648
F Agg-lbs	1767	1767	1767	1767	1786
Slump	0	0	0	0	0
Admix-lbs	0	3% 12	5% 20	7% 28	5.4% 20
Strength - psi					
1 Day f'c	1390	3910	3070	3320	3040
4 Day f'c	1750	5660	5550	5840	5890
7 Day f'c	4305	5730	6330	6355	6100
28 Day f'c	6670	9055	8095	10000	8005

Comments - Test "B"

As shown on the Graphs, a definite trend of acid resistance occurs with elapsed time as the crystalline develops.

Acid resistance displayed by the 19 day old concrete (Specimen IV) with XYPEX admix added paralleled the control concrete, indicating lack of crystalline growth sufficient to provide acid resistance characteristics.

Acid resistance displayed by the 25 day old concrete (Specimen V) with XYPEX admix added indicated a general 20% improvement of acid resistance characteristics.

40 day old sample (Specimen VI) displayed a general trend to 100% improvement of acid resistance until the pH of control sample solution reached a pH of 0.87 while the pH of Specimen VI solution remained at 0.71

The 139 day sample displayed a general 300% improvement.

Observation and monitoring of the pH during acid comparisons revealed the following:

1. 19 day old test - Collective increase to 0.92 pH
2. 25 day old test - Control to 0.85 - Admix to 0.77 pH
3. 40 day old test - Control to 0.87 - Admix to 0.71 - 0.74 pH

From : CCL'INC

PHONE No. : 214 517 4055

Sep. 15 1992 1:27PM P06

Permeability/Absorption

Due to the relative uncured condition of the concrete and the fact that residual moisture is present within the concrete, absorption comparisons utilizing methods of elevating temperatures above boiling point for an extended period of time have not been used.

In order to determine both permeability characteristics and concrete tendency to absorb water, pressure assisted testing was completed similar to the Army Corps of Engineering permeability test:

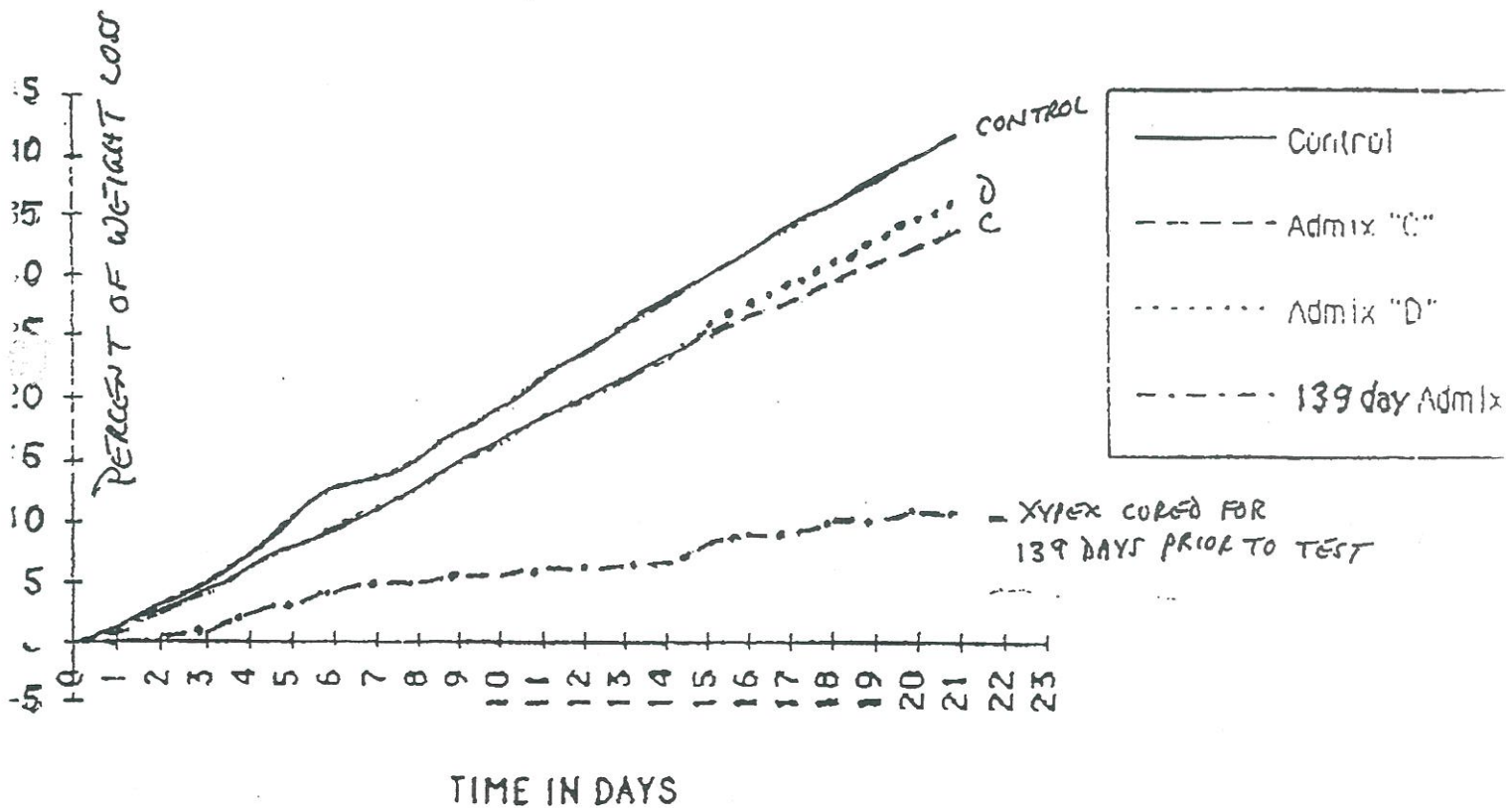
1. Pressure of 150psig (350 ft head) was applied for a period of 5 days (120 hours) to a 2" thick core prepared from Specimen IV concrete.
2. At the end of the test period, apparatus was disassembled and Specimen IV concrete was inspected.
3. Inspection revealed no permeation through the 2" sample.
4. After inspection, Specimen IV concrete was broken and revealed minor water penetration to a depth of 1-1/2 cm.
5. The concrete is impervious to water at a head of 350 ft and the absorption rate is extremely low.

Conclusions

- Depending upon the amount of admixture the compressive strength of concrete increased an average of 21% to 50% compared to the control mix.
- A 7% reduction in cementitious material compared to the control mix resulted in a 20% increase in compressive strength and a minimum 181% increase in acid resistance.
- XYPEX admix concrete is consistently 1.5 to 3 times more resistant to H_2SO_4 as standard concrete.
- XYPEX admix is impervious to water at 350 foot of head pressure (152 psi)
- Based on the tests of 19, 25, 40 and 139 days old concrete the resistance to sulfuric acid increases with elapsed time as the dendritic crystalline fiber matrix is allowed to develop and mature.
- Trends clearly indicate that a properly designed, quality controlled and concrete with XYPEX admixture will provide and maintain a 300 to 400 percent H_2SO_4 acid resistant improvement compared to conventional concrete.
- Utilization of the same solution throughout the acid comparison evaluation provides for an increased acid neutralization to a greater extent in the solution of the specimen sample being most deteriorated. In determination of comparative resistance, this method is effective for general comparative analysis, but tends to become increasingly inaccurate after day 3 or 4, dependent upon acidic liquid volume and specimen surface area and mass. The inaccuracy is always in the presentation of better performance for the specimen most affected.
(It is interesting to note in Test "B" that control samples increased the pH and depending upon the age of the specimen there was a distinct difference in the increase of pH which indicates that the acid was not able to attack the XYPEX specimens as aggressively even though the same amount of the cementitious materials was present.)
- Test results have all been very good, and indicate XYPEX as an admix will provide a distinct advantage in numerous concrete applications. The area of Chloride Ion protection is of particular interest due to the inability of a liquid vehicle, or carrier, to permeate into the concrete.
- Proper wet curing after placement of concrete with XYPEX as an admix eliminates curing cracks and additional wetting immediately after curing assures no water penetration.
- XYPEX admixture should be considered for use in all structures in contact with wastewater.

25-DAY CURE

25-DAY CURE ACID COMPARISON TEST - 7% H₂SO₄ SOLUTION
pH .7



40 DAY CURE ACID COMPARISON - 7% H₂SO₄ Ph .7

