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This pilot study has developed successful laboratory test methods which detect the entry and exit of moisture in concrete specimens. These methods include measurements of weight change and measurements of the change in the internal electrical resistance of the concrete.

In addition, this study has found that the effectiveness of at least some products has a tendency to diminish with repeated wet/dry cycles. Recommendations are offered for a final study to develop a standard test method for evaluation of the effectiveness and life expectancy of treatments.

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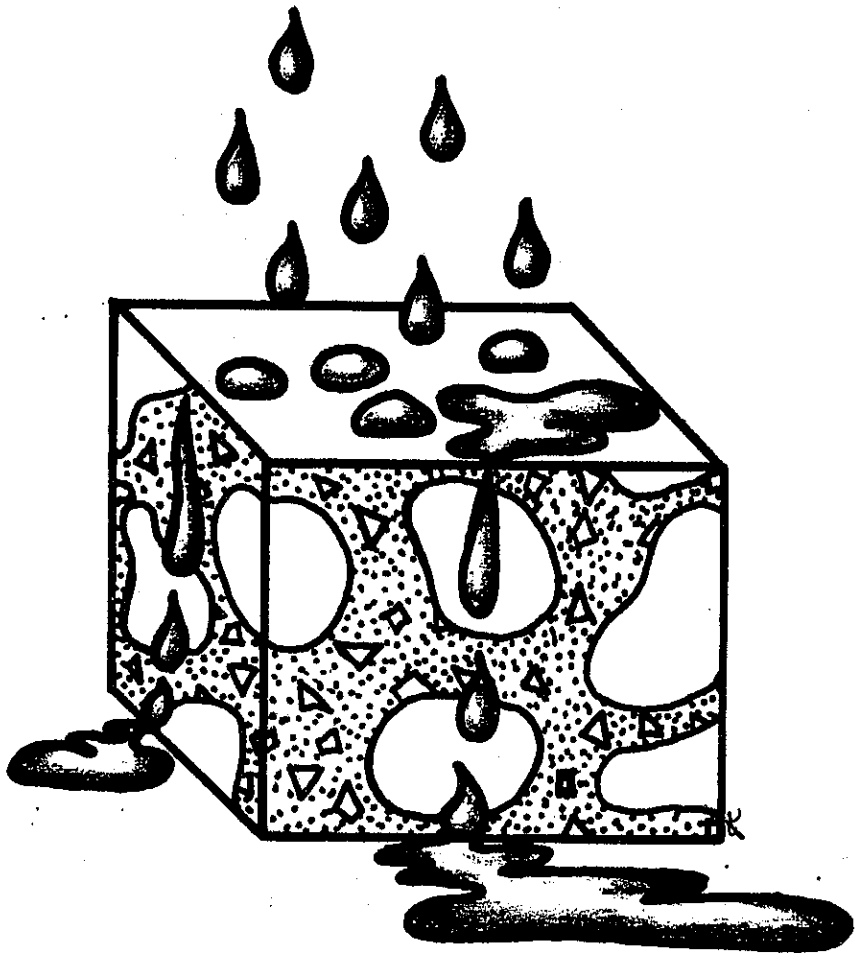
PILOT STUDY - LABORATORY TESTING OF THE ANTI-CORROSION EFFECTS OF PENETRATING SEALANT TYPE MATERIALS ON CONCRETE



FINAL REPORT

JUNE 1979

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CALIFORNIA DEPARTMENT OF TRANSPORTATION

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

June 1979

TL No 643294

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

PILOT STUDY-LABORATORY TESTING OF THE ANTI-CORROSION EFFECTS OF PENETRATING SEALANT TYPE MATERIALS ON CONCRETE

Study made by . . . . . Roadbed & Concrete Branch

Under the Supervision of . . . . Donald L. Spellman, P.E.

Principal Investigator . . . . . John Apostolos, P.E.

Report Prepared by . . . . . John Apostolos, P.E.

Very truly yours,

Neal Andersen

NEAL ANDERSEN, P.E.
Chief, Office of Transportation Laboratory

Attachment

JA:nb

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INTRODUCTION

Portland cement concrete is pervious to water, which infiltrates through cracks or by capillary action. Salt-laden water, from de-icing operations or marine environments, eventually reaches the reinforcing steel, causing it to corrode. The resulting corrosion products induce internal stresses which eventually result in spalling and general deterioration of the concrete. In addition, infiltrating water subjected to freeze/thaw environments can create stresses which cause similar destruction.

A significant reduction in the permeability of concrete would provide some protection from these destructive forces. Modern technology calls for anti-permeability treatments such as air-entrainment and lower water/cement ratio for reinforced concrete in critical environments. These measures, while helpful, do not provide adequate long-term protection. In addition, a significant number of structures have been built without the benefit of any special treatment, and are thus devoid of protection. Therefore the potential benefits from an effective sealant have great significance.

Various proprietary chemicals are currently being marketed, which - it is claimed - penetrate in liquid form and seal the concrete interstices, resulting in water-repellent or water-resistant layers immediately below the surface. Penetrants in this respect are different from "waterproof" surface coatings which seal by virtue of a continuous film of material on the surface, subject to easy damage by abrasion. Thus these penetrants offer some advantages over surface coatings (paints) in that they are less susceptible to deterioration through the effects of sunlight or abrasive wear; and in that most types permit water vapor to pass, thus allowing saturated concrete

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to lose moisture during periods when vapor pressures within the concrete are greater than in the surrounding atmosphere.

The California Department of Transportation requires the development of a method of evaluating the effectiveness of such products, whose number is expected to increase in the future.

This report presents the findings of a pilot study whose purpose is to aid in developing a standard test method for evaluating penetrating sealers.

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CONCLUSIONS

1. This pilot study has shown that at least two simple measurements may be used as detectors of water penetration into concrete, and thus would be prime tools in determining the effectiveness of concrete sealers. These measurements are:

a) Change in weight of concrete. (Dry vs. wet environment.)
b) Change in electrical resistance of concrete.

Weight change measurements are suitable for laboratory work and small, easy to handle specimens, whereas electrical resistance measurements are preferable for field installations and large, difficult-to-handle specimens. Both types of measurements can and should be used concurrently where possible.

2. Measurements of "half-cell" or "standard reference electrode" potentials were found unsuitable as detectors of water penetration into concrete.

3. On the average, untreated specimens absorbed 3 to 7 times more water than "sealed" specimens (treated with Macgobar Industries' "Chem-Trete"). Upon immersion in water, the internal resistance change of untreated specimens was 3 to 5 times greater than the change of "sealed" specimens. It was also noted, however, that repeated wet/dry cycles tended to gradually reduce the effectiveness of this particular sealer.

4. Depth of penetration of sealer varied from 1.3 to 5mm, and averaged 2.5 to 3mm, indicating it would not protect surfaces subject to severe abrasion such as pavement surfaces.

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IMPLEMENTATION

An additional study should be conducted, whose purpose would be to develop a standard laboratory method for evaluation and approval of proprietary concrete sealers.

This study should contain the following elements:

1. A literature search.

2. Contact with FHWA, NCHRP, and other States to solicit their experience with products having similar intended function.

3. Final development and design of laboratory test specimens.

4. Wet-dry cycling to determine effective lives of treatments.

5. Accelerated weathering.

6. Coordination of laboratory tests with field installations.

7. Determination of suitability of sealants for use on bridge structures for the purpose of preventing or retarding the movement of salt into the concrete.

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PROCEDURE:

1. Development of Test Specimens

Test specimens were designed to provide a maximum amount of information using a minimum quantity of pieces, time and effort. The following considerations affected the final specimen design:

a) Size and weight kept low for convenience and portability.

b) Both concrete and sand-cement mortar tested for suitability.

c) Effect of sealants on fresh and mature concrete to be evaluated.

d) Effect of sealants applied to salt-impregnated concrete or mortar to be evaluated.

e) Control of water entry and exit.

f) Detection of water infiltration achieved through several independent methods, including standard techniques used in corrosion surveys.

The resulting specimens consisted of blocks measuring 6.3 x 7.4 x 14.0 cm, and weighing 1.6 kg. Each was composed of two layers, a sand-cement mortar slab cast on top of an aggregate concrete slab, as shown in fig. 1. Half of the specimens contained salt-impregnated mortar, mixed at the rate of 10% chloride ions by weight of cement. Two steel discs, with insulated electrical leads attached, were cast into the mortar.

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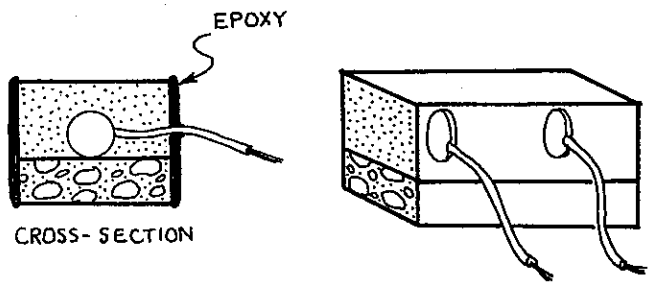

Fig. 1. Schematic of typical test specimen

The discs were 2.1 mm thick cross-sections of a 60-grade, No. 8 reinforcing bar, spaced 8 cm apart, and were used as internal electrodes for subsequent electrical measurements. With the exception of the top and bottom sides, the remaining four sides of the specimens were coated with a flexible epoxy to render them waterproof.

Following the casting of the mortar on the concrete slabs, the specimens were placed in a "fog room" (95+% relative humidity) for 7 days, then allowed to dry at room temperature until their weight stabilized (20 days). Epoxy coating was performed at that time, and the two uncoated sides were given a light sandblast to remove slight contamination caused during the epoxy application.

At this point, all specimens (total 8) were placed in a 65°C (150°F) oven for 18 hours, and after being allowed to cool, were then ready for experimentation.

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2. Application of Sealant

Since the purpose of this project was to develop and evaluate testing techniques, rather than to evaluate various sealants, only one product was selected for use. This product, marketed under the trade name "Chem-Trete Silane" by Magcobar Industries, was one of four competing products previously tested by the Transportation Laboratory. The results of these tests indicated Chem-Trete would be effective in retarding entry of water into concrete. (Memo to file by Ed Budney, "Absorption Tests on Xypex, Chem-Trete, Conseal, and Ma/Con" dated 12/1/78 and included as an appendix to this report.)

Of the 8 specimens, 4 were treated with sealant, and the remainder were untreated to act as controls. The treated specimens included two with "salty" mortar and two with plain mortar.

Application was made as per manufacturer's recommendations, using a brush, and adding sealant until the surfaces retained the darker "wet" look for approximately one minute following application. The rate of application was measured at 409 square feet per gallon on the concrete side and 164 square feet per gallon on the more porous mortar side. (Manufacturer's guidelines indicated 400 sq ft/gal for dense concrete and 100 sq ft/gal for porous stucco.)

3. Test Measurements

Three independent techniques were used in the attempt to detect and/or measure absorption of water by specimens:

a) Weighing: Water absorption is indicated by an increase in weight of the specimen. The only instrument required is a weighing scale. This is the simplest method and is the one

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usually employed for absorption studies, and used to show effects of products in their advertising literature. The Oklahoma D.O.T. is currently using this method for product acceptance on an experimental basis.

Disadvantage: Suitable for small, portable specimens only.

b) Electrical Resistance: Water absorption is indicatedd by a decrease in the electro-chemical resistance of the ecimen. This method, discussed in greater detail later, requires suitable electrodes embedded in the specimen (such as the two steel discs). The instrument used is a "resistivity meter" of specialized function, rather than a common ohm-meter which is unsuitable for measurements of this nature. This is the simplest electrical method available.

Disadvantage: Resistance changes with specimen temperature.

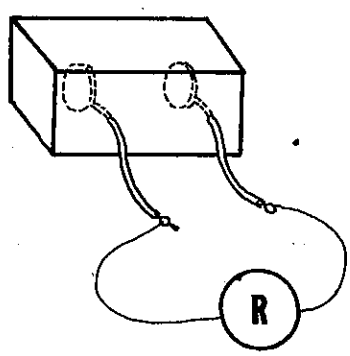

Fig. 2. Schematic of resistance measurement

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c) Electrical Potential: Tendency of embedded metals to corrode is indicated by a change in electrical potential (voltage) between the metal and a standardized electrode. This method requires that a metal be embedded in the specimen, and a direct electrical contact be made between the metal and the voltage-measuring instrument. It is a popular method for the detection of corrosion tendencies of metals in their environment.

Disadvantage: Time-consuming, and difficult to obtain reliable readings from small specimens.

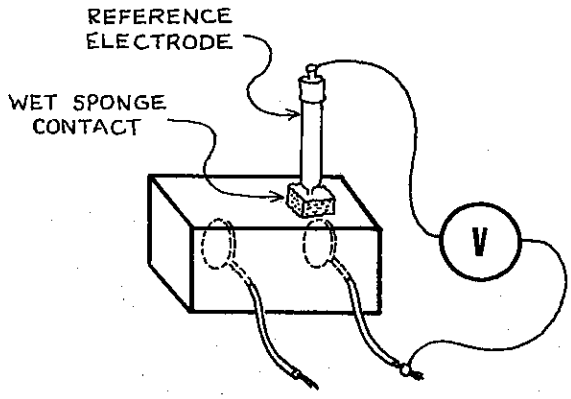

Fig. 3. Schematic of standard electrode measurement

4. Performing the Experiment

Four of the eight specimens were kept dry on the laboratory bench as controls, while the other four were subjected to various cycles of water immersion and drying. In order to test the characteristics of the mortar and concrete side independently, the specimens were not totally immersed in water, but placed inside a pan. Wooden dowels were employed to support the specimens off the bottom of the pan, and the water level was adjusted to 1 cm above the bottom of the specimen. Entrapped air bubbles were carefully removed.

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Distilled water was used. The two specimens containing salty mortar were placed in a separate pan from the two specimens containing plain mortar.

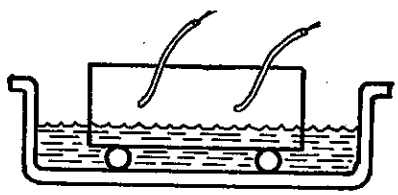

Fig. 4. Schematic of immersion

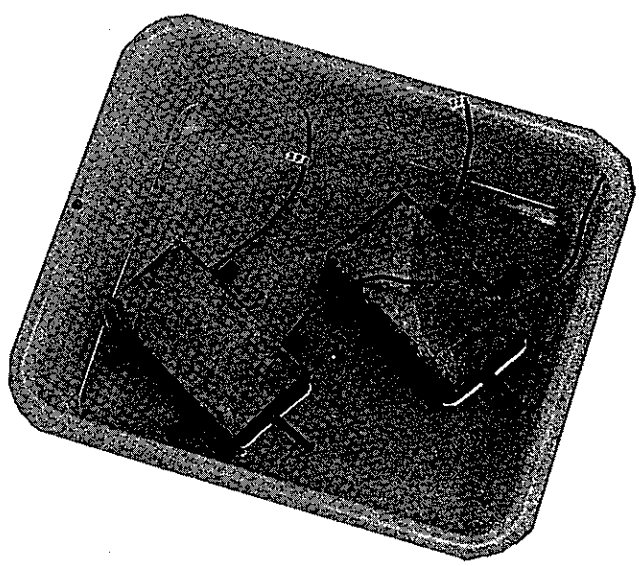

Fig. 5. Typical one-side immersion of specimens. Nylon bolts have been cast into one side to facilitate handling.

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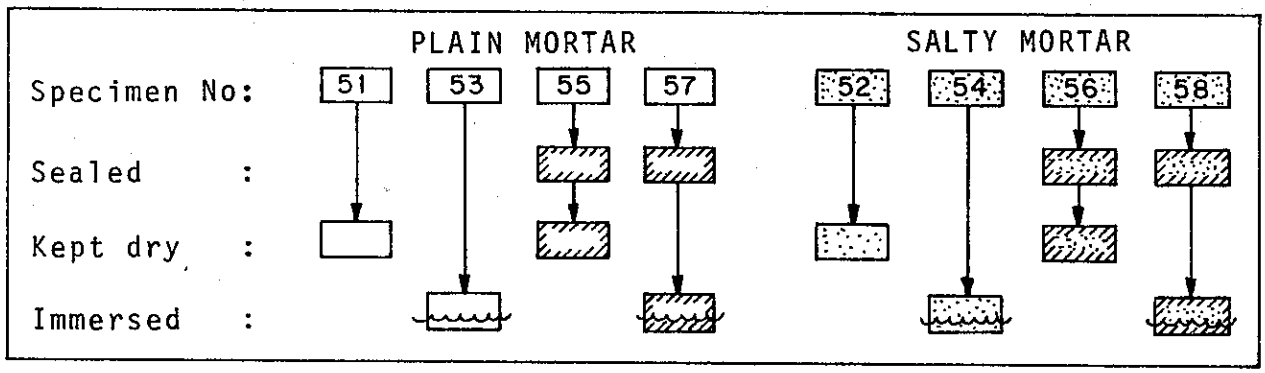

Fig. 6. Schematic: Distribution of test specimens

The four immersion specimens received identical treatment throughout the wet-dry cycles. The four non-immersed specimens also received common treatment, i.e., placed together on the laboratory bench (20°C ± 2°, 50% ± 10% relative humidity).

Weight, electrical resistance, and half-cell potential measurements of all specimens were taken at frequent intervals throughout the 4-month duration of the experiment. The first two types of measurements were made almost daily, but the half-cell potential readings were beset with difficulties, and thus were only taken occasionally, as time permitted. (These difficulties were primarily due to the nature of small specimens which, when subjected to potential measurements, provide rapidly decaying voltages which are difficult to read accurately, and are also influenced by the amount of oxygen absorbed by the drying mortar and concrete.)

Test data have been plotted in the accompanying graphs, figs. 7 through 10.

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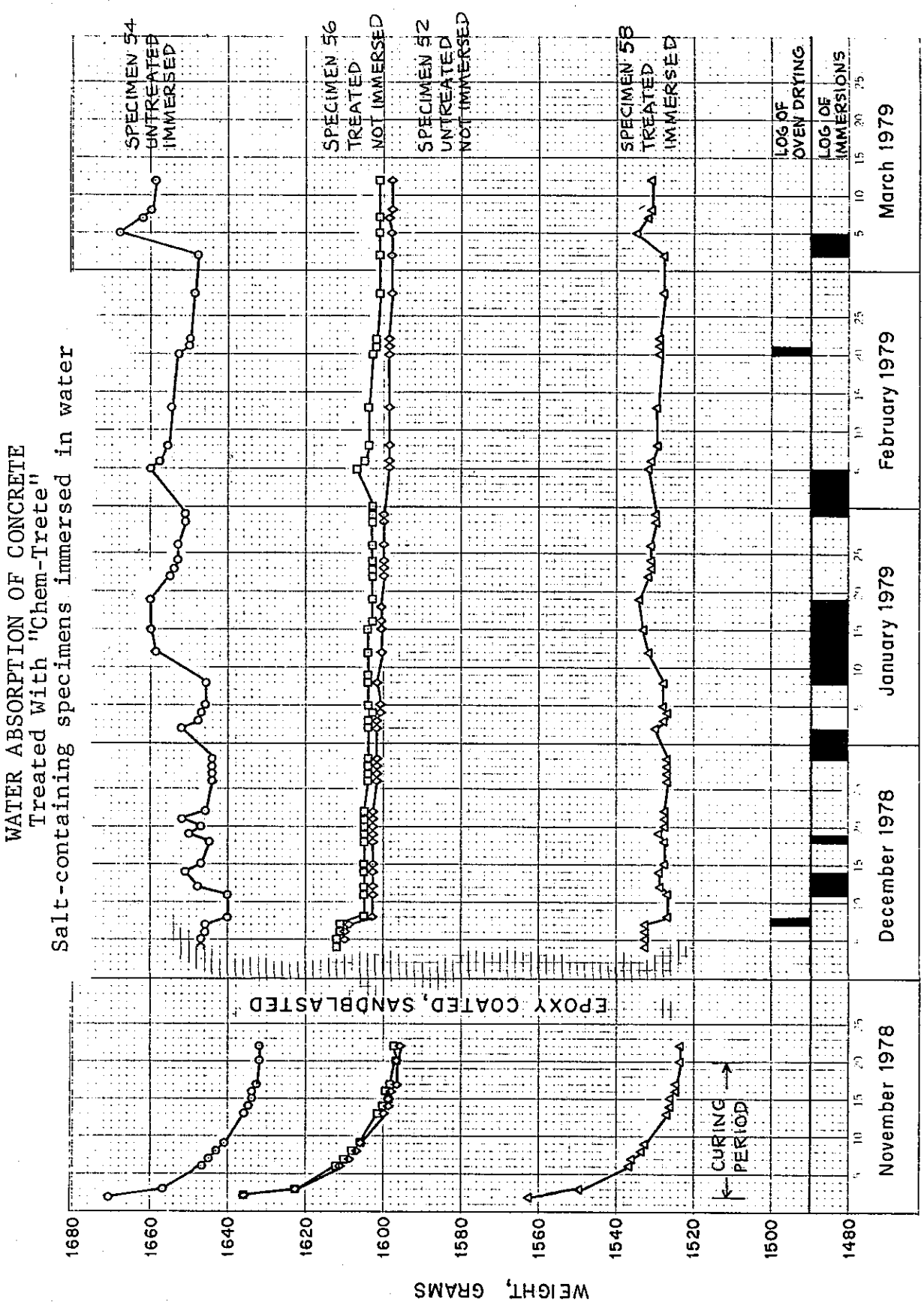

Fig. 7

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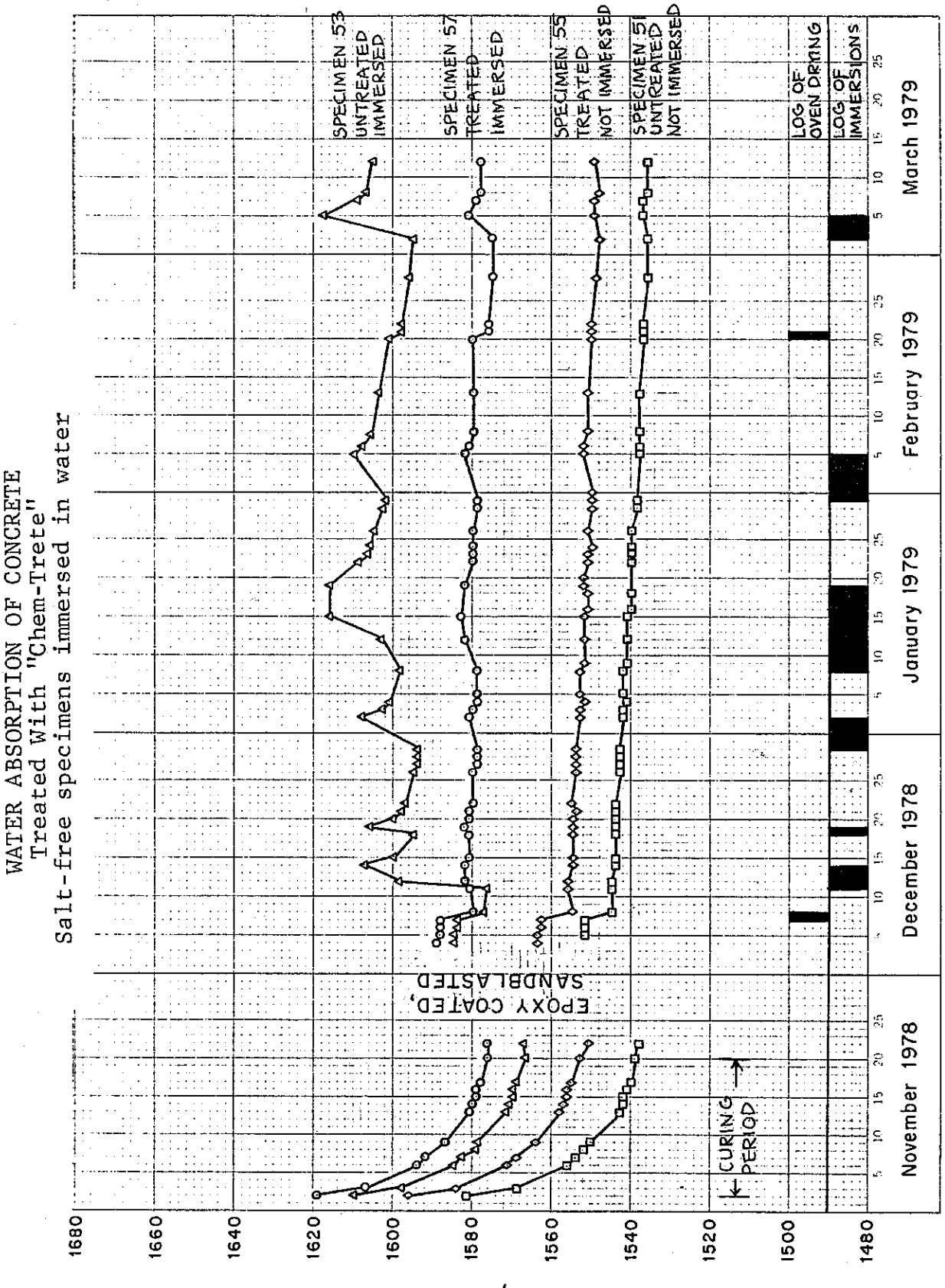

Fig. 8

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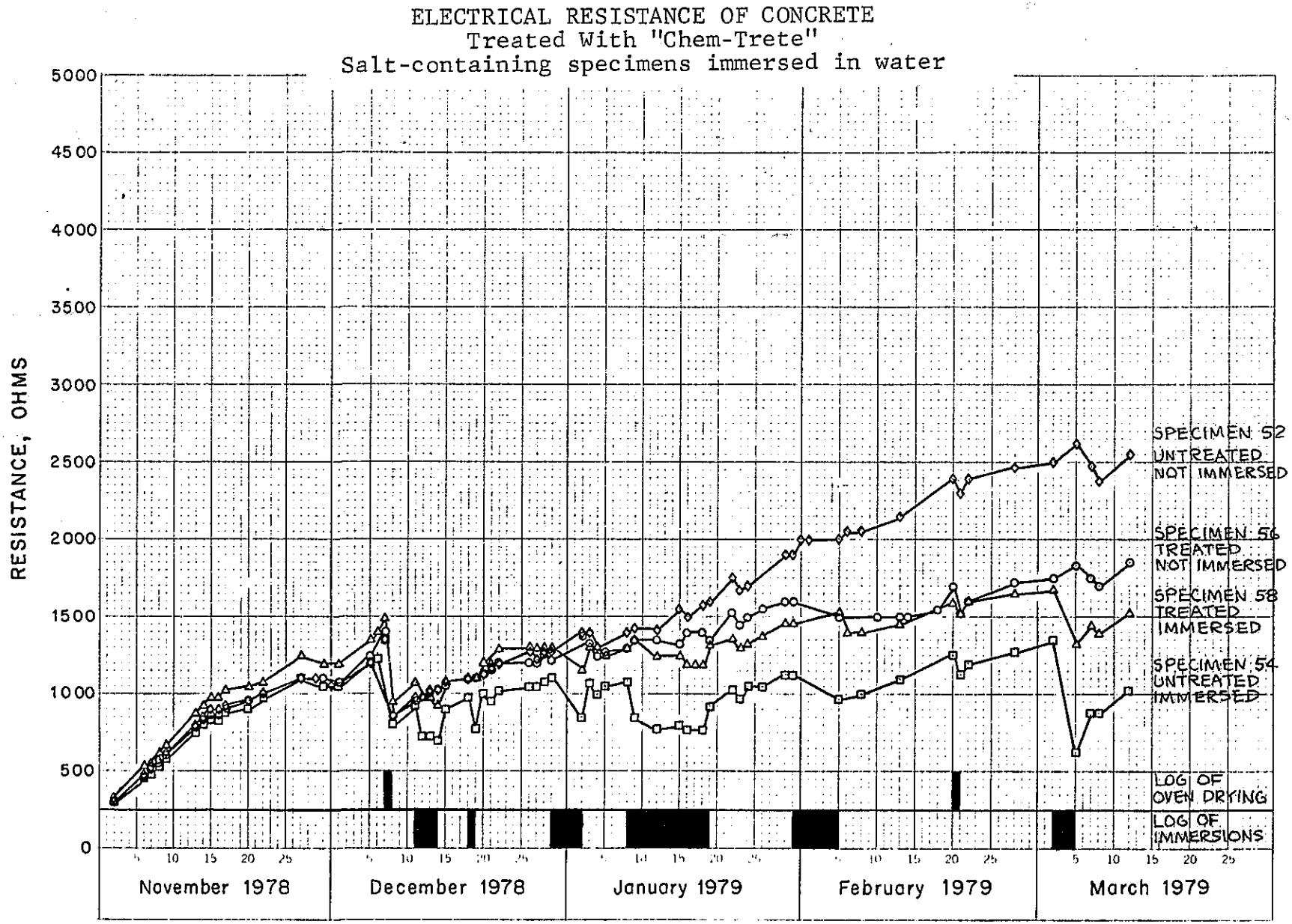

Fig. 9

ELECTRICAL RESISTANCE OF CONCRETE
Treated With "Chem-Trete"
Salt-free specimens immersed in water

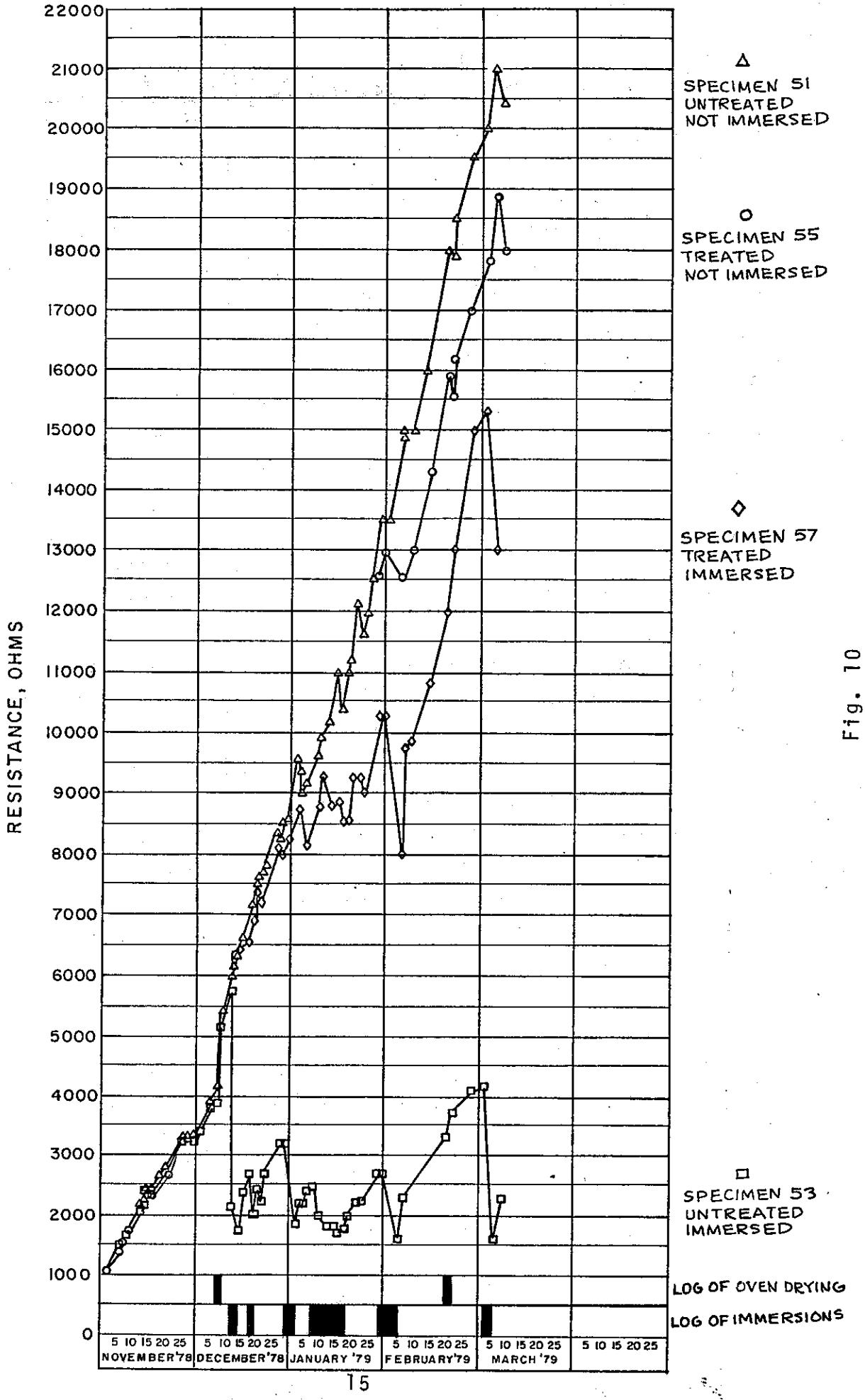

Fig. 10

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DISCUSSION OF TEST RESULTS

1. Behavior of Test Specimens

a) Both the sand-cement mortar and the concrete sides of the specimens exhibited similar properties of water absorption and drying, as well as electrical resistance. Either material appears to be satisfactory for specimen preparation.

b) The particular sealant used in the experiment imparted similar properties to both the one-year-old concrete and the newly-cast sand-cement mortar specimens. (The quantity of sealant absorbed by each material was, of course, dependent on its porosity.)

c) Both salt-containing and salt-free specimens exhibited similar water absorption and drying characteristics.

All internal resistance measurements of the salt-containing specimens were substantially lower than measurements of the salt-free specimens, as expected. This may mean that application of the sealant to salt-containing concrete would not offer any benefit because the electrical resistance of the concrete will always be too low to significantly inhibit corrosion of imbedded steel. Both types indicated water absorption and drying by marked changes in their resistance values, but these changes were more prominent in the salt-free specimens.

"Half-cell potential" measurements were markedly different between salt-containing and salt-free specimens as expected, with the former exhibiting values in the range normally associated with the onset of corrosion, and the latter exhibiting values of lesser magnitude, in the range of no corrosion.

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The particular sealant used in the experiment imparted similar properties to the salt-containing and salt-free specimens, and either material appears to be satisfactory for specimen preparation. There is, however, no assurance that other sealants will react satisfactorily with salt-containing concrete.

d) The steel discs embedded in the specimens performed their function without flaw. Careful spacing (8 cm $\pm$ 0.5 mm) at the time of casting the mortar resulted in initial resistance measurements varying by less than 2% between any salt-free specimens, and less than 8% between any salt-containing specimens.

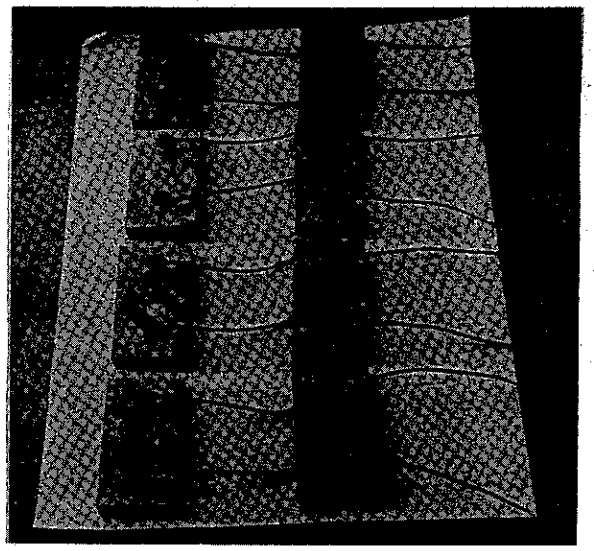

Fig. 11. Steel discs attached to concrete blocks with cyanoacrylate adhesive prior to casting mortar around them

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e) Depth of penetration of the sealant into the specimens was very shallow, indicating that its use on surfaces subject to abrasion would be limited. At the end of the testing, all treated specimens were broken. Wetting the broken surface revealed the areas where the sealant had penetrated as a light gray colored area against the darker, "wet look" of the remaining cross-section. Penetration depths were as follows:

Material	Range of Penetration		Average Penetration	
	mm	(inches)	mm	(inches)
Concrete	1.3-5.0	(.05-.20)	2.5	(.10)
Mortar	1.3-5.0	(.05-.20)	3.0	(.11)

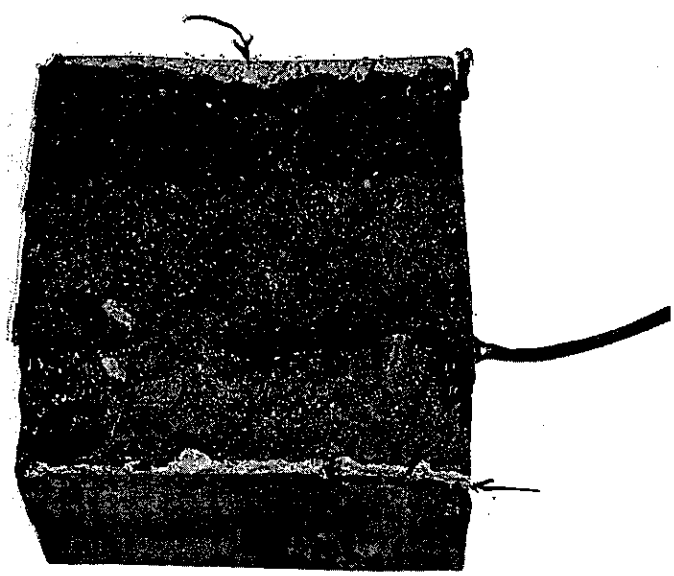

Fig. 12. Broken specimen showing typical penetration of sealant into mortar (top) and concrete (bottom).

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2. Performance of Instruments and Measurement Methods

a) Weighing was performed on a scale accurate to ±0.5 gram. Water absorption caused weight changes in the neighborhood of 12 grams for untreated specimens and 3 grams for "sealed" specimens. These values translate to absorption rates of 1200 grams/metre^2 and 250 grams/metre^2 respectively, of surface area in contact with water. Drying rates, obtained by placing specimens in a 120°F (48.9°C) oven for 25 hours, indicated a slightly higher rate of drying of untreated specimens than treated ones. This is probably due to the fact that untreated specimens, after immersion, simply had more moisture available to escape.

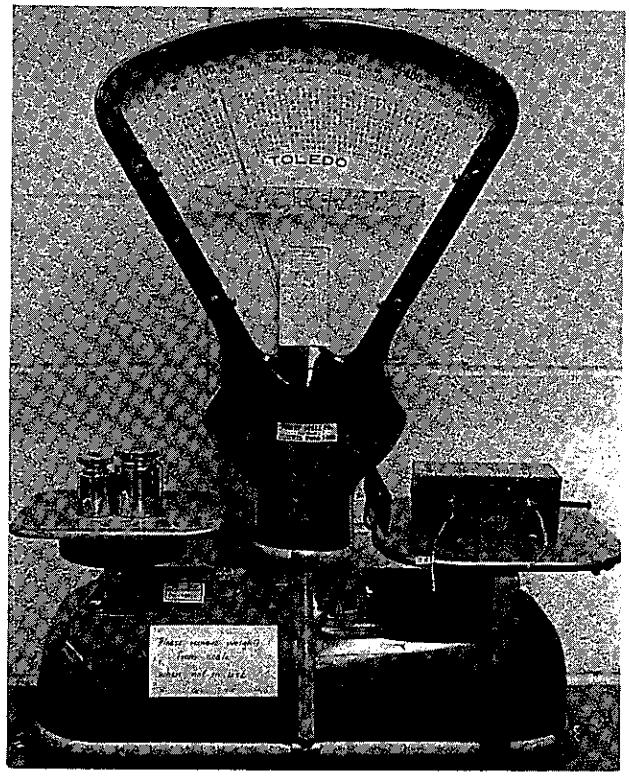

Fig. 13. Weighing of specimens

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It should be noted that available literature presents absorption data in terms of "% increase in specimen weight" of small cubes or blocks fully submerged in water. Such units, although in common use, tend to be sensitive to influences of the physical size and shape of specimens. It is proposed that data be presented in units of "weight gain per surface area in contact with water", i.e., $\underline{\text{grams/cm}^2}$, which can be easily extrapolated to larger specimens and full-size structures.

Weight measurements should be made on specimens which have been cast well in advance of testing. This is necessary in order to allow hydration, evaporation, and the resulting weight loss of fresh concrete to stabilize. As can be seen on Figs. 7 and 8, the mortar segment of the specimens took three weeks to stabilize* in weight after removal from moist cure. Even after stabilizing, the specimens which were not subjected to immersion continued to steadily lose weight at the rate of one gram per month at room temperature.

*"Stabilization" in this project was considered as being achieved when specimen weight changed by 1 gram per week or less.

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b) Electrical resistance of specimens was measured with a soil resistance meter. This instrument is a null balance ohmmeter which, when balanced, should not influence the behavior of the specimen being tested. It generates an 8 to 14 volt, square wave, 97 Hz A.C. current. The A.C. mode prevents the electrochemical reaction within the specimen from "polarizing", or slowing down, through ion-starvation, by being driven in one (D.C.) direction. (Common ohmmeters operate in low voltage D.C. modes, have a relatively low input impedance, and together these features have an adverse influence on measured values.)

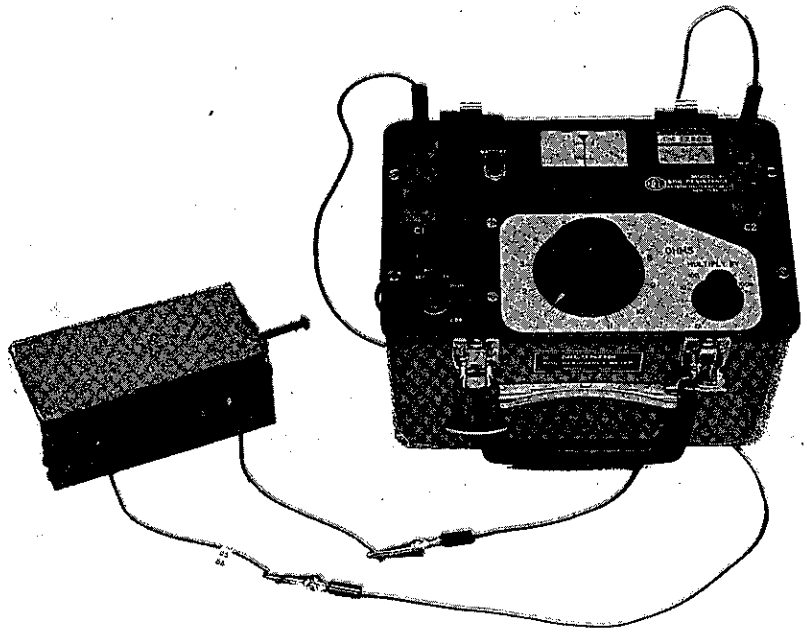

Fig. 14. Typical resistance measurement.

Resistance measurements were quick, easy, and repeatable. Specimen temperature, however, has a significant - but predictable - influence on such measurements, necessitating

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the use of control specimens for comparison. Generally, a rise in temperature causes a drop in resistance. (Incidentally, this means that during freezing weather, corrosion is greatly retarded due to the high internal resistance. Corrosion activity is greater during the thaw-out in warm weather, before water has had a chance to evaporate from the concrete interstices).

Water absorption-caused drops in resistance values averaging as shown in the table below:

Specimen	Resistance Drop
Untreated:	
Salt-Free	1600 ohms
Salt-Containing	290 ohms
Treated:	
Salt-Free	800 ohms
Salt-Containing	100 ohms

Drying-out of specimens* generally increased resistance at the rate of 160Ω/day for salt-free specimens and 20Ω/day for salt-containing specimens. This was also true for controls, which were never immersed.

*At laboratory normal room environment (≈70°F, 50-60% Rel. Hum.)

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c) Electrical Potential of specimens was measured using a standard Fiber Junction Reference Electrode - This is an instrument utilizing a Mercury-Mercurous Chloride ("Calomel") internal element surrounded by an electrolyte composed of saturated potassium chloride. The common jargon name for this type of instrument is "half-cell", derived from the fact that when appropriately connected to another electrode (such as the steel discs in the specimens), a "full" battery cell is created which delivers a measurable voltage. The voltmeter used to measure this voltage is of exceptionally high input impedance (10^{10} ohms) to minimize the effect of instrumentation on these extremely weak "cells".

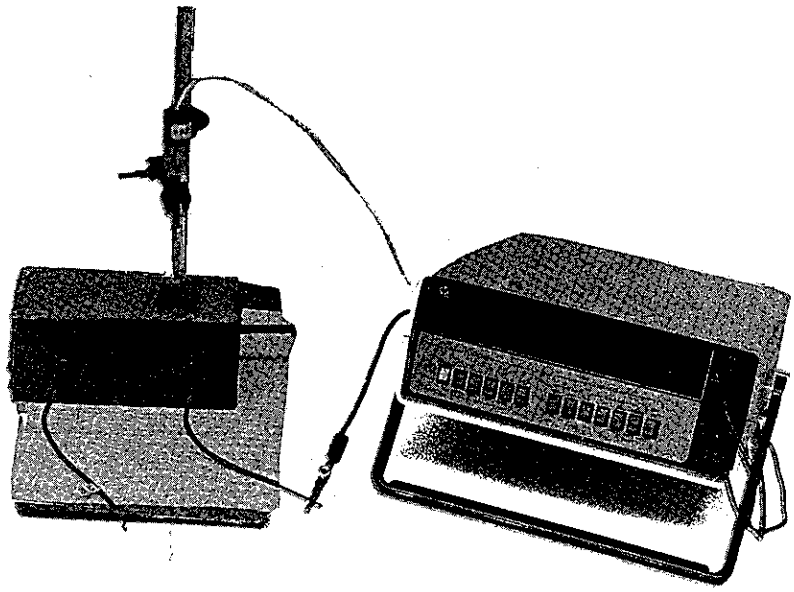

Fig. 15. Typical half-cell potential measurement.

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In practice, it was found that the very small size of the specimens created an extremely weak "cell", and voltage readings were not constant, but decayed rapidly. Steady-state voltages were achieved after 1 to 10 minutes, which made measurements of the eight specimens (total 32 readings) very time-consuming. Use of a chart-recorder was rejected because such instruments have a much lower input impedance, and thus would adversely influence the measurements.

Generally, these "half-cell potential" measurements did not indicate the absorption of water that was taking place with any degree of certainty. This method was significantly inferior to the weighing and resistance-measuring methods, in both time consumption and quality of results. Since this fact became obvious early in the experiment, such measurements were taken only occasionally, interspersed throughout the length of this project.

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3. Analysis of Data

The four specimens selected for immersion were No's. 53, 54, 57, and 58, the latter two having been treated with sealant, and the former two left untreated.

The log of immersions is presented in the table below:

Date Immersed	Date Removed	Tot. Hours Immersed	Comments
12/11/78	12/14/78	67.3	Mortar side in contact with water
12/18/78	12/19/78	23.3	" " " " " "
12/29/78	1/2/79	95.5	" " " " " "
1/8/79	1/19/79	268.4	Concrete " " " " "
1/30/79	2/5/79	145.3	Concrete side in contact with saturated NaCl water in envir. chamber at 29°F-35°F for 2 days, then allowed to reach room temp. ≈70°F.
(2/20/79)*	(2/21/79)	(25.2)	(Placed in oven 120°F to accelerate drying & observe.)
3/2/79	3/5/79	63.9	Specimens completely immersed in water

*Not immersed: Presented in this table as a chronological event.

The change in specimen weight resulting from absorption of water was converted to absorption rates, in terms of "grams of water absorbed per square centimeter of surface area in contact with water", as discussed earlier. The term "surface area" as used here refers to the projected planar surface, and not to the microscopic area involving surface irregularities, pores, voids, etc. Absorption rate comparisons are presented in the following tables.

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a. Unsalted specimens (#53 and #57)

Consecutive Order of Immersion	Side in Contact With Water	Absorption Rate grams/cm^2		Relative Rate Untr./Treat.
		Untreated	Treated	
1	Mortar	.300	.010	30
2	Mortar	.110	.010	11
3	Mortar	.140	.020	7
4	Concrete	.156	.028	5.6
5	Concrete	.074	.028	2.6
6	Both	.110	.029	3.8
Mean Values:		.148	.021	7.1

b. Salted specimens (#54 and #58)

Consecutive Order of Immersion	Side in Contact With Water	Absorption Rate grams/cm^2		Relative Rate Untr./Treat.
		Untreated	Treated	
1	Mortar	.105	.022	4.8
2	Mortar	.048	.011	4.3
3	Mortar	.077	.034	2.3
4	Concrete	.129	.055	2.3
5	Concrete	.083	.018	4.5
6	Both	.094	.035	2.7
Mean Values:		.089	.029	3.1

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Since the internal resistance of concrete is never constant, but changes with time, temperature and moisture level, measured values were converted to relative terms through use of "% change" figures, by the following formula:

$$\% \text{ Change} = \frac{100X(\text{Resistance before immersion} - \text{Resistance after immersion})}{\text{Resistance before immersion}}$$

Resistance change comparisons are presented in the following tables.

c. Unsalted specimens (#53 and #57)

Consecutive Order of Immersion	Side in Contact With Water	% Change in Resistance		Relative Rate Untr./Treat.
		Untreated	Treated	
1	Mortar	72	8.5	8.5
2	Mortar	31	6.5	4.8
3	Mortar	43	6.7	6.4
4	Concrete	21	6.0	3.5
5	Concrete	17	6.8	2.5
6	Both	62	15.0	4.1
Mean Values*		36	7	5

*Mean values were computed after data from immersion No. 6 were normalized to single-side contact with water (by using 1/2 the values for % change in resistance given in the table).

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d. Salted specimens (#54 and #58)

Consecutive Order of Immersion	Side in Contact With Water	% Change in Resistance		Relative Rate Untr./Treat.
		Untreated	Treated	
1	Mortar	25.5	13.6	2
2	Mortar	20.4	2.7	8
3	Mortar	22.7	11.5	2
4	Concrete	15.1	-2.3	16
5	Concrete	15.5	6.9	2
6	Both	53.1	20.8	3
Mean Values*		21.0	7.1	3

*Mean values were computed after data from immersion No. 6 were normalized to single-side contact with water (by using 1/2 the values for % change in resistance given in this table).

The preceding tables indicate that water penetration can be detected by weight and resistance measurements, in both salt-containing and normal concrete mortar. The relative rate of water penetration of treated (sealed) vs. untreated specimens is of such magnitude that comparisons are easy and obvious. Another indication is that, on repeated wet-dry cycles, the sealant's properties appear to weaken somewhat. This poses the need for cyclic testing as part of formal evaluation procedures.

Measurements of electrical potential were taken at random intervals which did not necessarily coincide with dates and times immediately before and after immersion. The data do not correlate with the events, and will not be presented in this report. As discussed earlier, this method is not suitable as a detector of water infiltration.

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APPENDIX A

Manufacturer's Literature, "Chem-Trete" ®

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Chem-Trete® Silane

A new kind of weatherproofing agent

Chem-Trete Silane is a revolutionary new product that weatherproofs concrete and masonry surfaces without altering the natural surface appearance and texture. *It should NOT be confused with conventional "Silicone" coatings regardless of any name similarity.* Unlike coatings, oils and other currently used sealants, the Chem-Trete Silane does not block the porosity or permeability of concrete. Instead, it reacts chemically with the surface of the structure to form a new surface, repellent to liquid water yet still permeable to water vapor.

The water repellent surface formed is highly effective against weathering and discoloration. In preventing moisture entry, it eliminates many of the major causes of failure of masonry and concrete, such as reinforcing bar corrosion, salt leaching and freeze-thaw cracking. Its durability (on reactive surfaces not subjected to abrasive or frictional wear) is backed by a limited 5-year performance guarantee, conditioned on proper preparation of the surface and *proper application* of the Chem-Trete Silane solution.

Chem-Trete Silane has demonstrated long life by continued superior performance in numerous applications in Europe over the past decade.

Description:	Highly mobile, colorless, neutral fluid
Active substance:	Alkyl-Alkoxy Silane of a given composition
Active substance content:	40%
Solvent:	Ethyl alcohol (Contains 2.15% Toluene by weight as a denaturant.)
Density D_4^{20}:	0.8
Viscosity 20°C (68°F):	0.95 mPA-s (previously cP)
Solidification point:	−30°C (−22°F)
Flash point:	Approximately 12°C
Chemical behavior:	Chem-Trete Silane is alkali-free. It will not attack metals.
Packaging:	Fifty-five (55) gallon drums and five (5) gallon cans.
Storage:	Chem-Trete Silane should be stored in a dry place away from direct heat, and should be protected against any contamination by water. Under these conditions, the Chem-Trete Silane may be stored for a virtually unlimited period of time.

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SPEC® DATA

This Spec-Data Sheet conforms to editorial style prescribed by The Construction Specifications Institute. The manufacturer is responsible for technical accuracy.

DAMPPROOFING

1. PRODUCT NAME

Weatherproofing Agent
Chem-Trete® Silane

2. MANUFACTURER

Magcobar Division,
Dresser Industries, Inc.
3202 Dresser Tower
P.O. Box 6504
Houston, TX 77005

Composition and Materials:

Description:	Highly mobile, colorless, neutral fluid
Active substance:	Alkyl-Alkoxy Silane of a given composition
Active substance content:	40%
Solvent:	Ethyl alcohol (Contains 2.15% Toluene by weight as a denaturant.)
Density D_{20}:	0.8
Viscosity 20°C (68°F):	0.95 mPA-s (previously cP)
Solidification point:	-30°C (-22°F)
Flash point:	Approximately 12°C
Chemical behavior:	Chem-Trete Silane is alkali-free. It will not attack metals.

3. PRODUCT DESCRIPTION

Basic Use: Chem-Trete Silane weatherproofs concrete and masonry surfaces without altering the natural appearance and texture. It reacts chemically with the material to form a new surface, repellent to water but still permeable to water vapor. The resultant water repellent surface is highly effective against weathering and discoloration. It eliminates the results of moisture penetration in masonry and concrete such as corrosion of reinforcing bars, salt leaching and freeze-thaw cracking.

Chem-Trete Silane can be used to protect:

- Roads
- Bridges
- Airport Runways and Taxiways.
- Major concrete construction projects (dams, bulkheads, etc.)
- Precast or prestressed concrete products.
- Architectural concrete (commercial and residential concrete, brick and stone-veneer-new and restoration).

Limitations: Chem-Trete is not intended for waterproofing under hydrostatic pressure but may be applied prior to laying down asphalt or painting.

4. TECHNICAL DATA

Moisture absorption: measured by ASTM-C-642. Eight concrete cylinders, 3 × 3 inches, were cured and oven-dried according to test procedure. Four were treated with Chem-Trete Silane and four not treated. The cylinders were then submerged in water for 48 hours, followed by 24 hours submersion in boiling water. Six of the eight, three treated and three not treated, were then resubmerged in water. Two were broken for visual observation. Measurements on the percentage increase in weight were recorded as shown in Table 1:

Table 1

Submersion Time	% Weight Increase Treated	% Weight Increase Untreated
48 hours soak	0.8	4.8
24 hours boil	1.3	5.0
7 days	1.5	5.2
14 days	1.7	5.2
21 days	1.7	5.3

Adhesion: measured using ASTM-D-3359-74 standard testing and measurement procedures on a treated and untreated concrete speciman. Results are shown in Table 2:

Table 2
Adhesion Numbers

Paint Type	Treated	Untreated	% Change
Acrylic	1-¾	1-¼	+40
Oil Base	2-¾	2	+38
Epoxy	1-¾	1-½	+17

Steel corrosion: Four blocks 12 × 12 × 8 inches with #4 reinforcing steel with ½ inch clear cover were fabricated. Two blocks were fabricated so that cracks were formed on the surface above the steel. One cracked and one not cracked were treated with Chem-Trete Silane.

The four blocks were stored alternatively for four days under 13.6% NaCl solution followed by 10 days drying.

Results are summarized for specimens treated and untreated with Chem-Trete Silane in both cracked and intact concrete slabs in Figure A.

Under these test procedures, a potential of -0.3 volts generally indicates that the rebar has entered the active corrosion stage.

DAMPPROOFING

5. INSTALLATION

Preparatory Work: Chem-Trete is a ready-to- use solution. Keep the container tightly sealed when not in use, since at-

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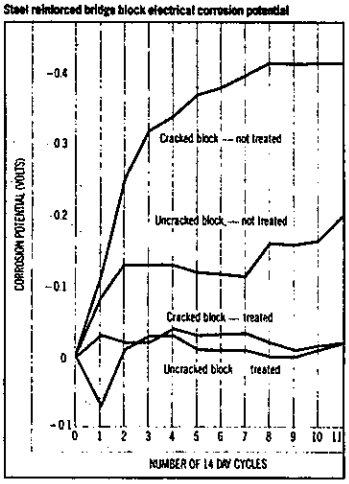
Figure A

Steel reinforced bridge block electrical corrosion potential



mospheric moisture will slowly react with and alter the Chem-Trete Silane solution. Its uniqueness requires slightly different application techniques than the usual coating or sealant. Chem- Trete may be applied to a damp or dry surface, although dry conditions are preferred to facilitate maximum penetration. All standing water must be removed. Surfaces should be clean and grease free prior to application. Chem-Trete silane should not be applied at temperatures below 32°F, or when the temperature is expected to fall below 32°F within 12 hours of application.

Methods: The recommended application equipment is a low pressure (15psi maximum) airless-type sprayer, such as a garden or form oil sprayer. However, a brush or roller may be used. Cover approximately eight inches with each spray pass in slightly overlapping patterns. When a brush is used, repeated applications should be made until the surface remains moist for a minute or so before all the solution disappears.

Apply Chem-Trete Silane until the solution runs or stands. Vertical surfaces should be treated from the bottom up. Proper quantities are being applied when excess solution runs six to eight inches below the spray pattern before penetrating the surface which has just been sprayed. Proper quantity on horizontal surfaces is indicated when solution stands for a few seconds before completely penetrating. Coverage will vary with the absorbency and surface texture of the substrate from 100 square feet/gallon for highly absorbant substrates to 400ft²/gallon for smooth (steel troweled) dense concrete.

Thoroughly wash all equipment and clothing after use. Chem-Trete is not stickly, so application equipment may be easily cleaned with water.

Precautions: Flammable—contains ethyl alcohol. Do not store or use Chem-Trete near heat, sparks or an open flame. Do not smoke in the vicinity where Chem-Trete is being applied. Use in a well-ventilated area or wear an air-supplied respirator. Always work in pairs. Always wear protective goggles and gloves. If inhaled, move immediately to fresh air. If breathing falters or stops, give artificial respiration, preferably mouth-to-mouth. Call a physician. In case of skin or eye contact, flush immediately with warm water for 15 minutes. Remove contaminated clothing and shoes. Call a physician.

Storage: Do not store in a glass container or near heat or open flame. Keep container tightly closed when not in use.

Disposal: This material is not subject to biological degradation. Dispose of unused material and concontainer in a proper landfill disposal site.

Keep this and all chemicals out of reach of children.

6. AVAILABILITY AND COSTS

Chem-Trete Silane is available from various stockpoints throughout the U.S. and Canada. Approximate material costs vary from 19¢ to 53¢ per square foot depending upon the type of surface treated. Costs will decrease based on quantity purchases.

7. GUARANTEE/WARRANTY

A. Seller warrants that the product will be of good quality when shipped and will be free from defects in material and workmanship.

B. All claims for defective CHEM-TRETE® must be made in writing immediately upon discovery, and in any event within ninety (90) days from shipment of applicable item. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS. Goods in question must be held for seller's inspection and returned by buyer to the original f.o.b. point of delivery.

C. Upon submission of a claim as provided above and its substantiation, seller shall at its option either (1) replace its product or (2) refund an equitable portion of the purchase price.

D. The foregoing is Seller's only obligation and Buyer's only remedy for breach of warranty, and except for gross negligence, willful misconduct, and remedies permitted under the PERFORMANCE, INSPECTION AND ACCEPTANCE and the PATENTS Clauses hereof, the foregoing is Buyer's only remedy hereunder by way of breach of contract, tort or otherwise, in no event shall Buyer be entitled to incidental or consequential damages. Any action for breach of this agreement must be commenced within two (2) years after the cause of action has accrued.

Product Performance: Performance of Chem-Trete® Silane may be guaranteed for a period of five (5) years from date of application, upon buyer's written request for a specific application approved by seller.

8. MAINTENANCE

None required. Surfaces may be retreated at the end of service life.

9. TECHNICAL SERVICES

For further technical information, pricing, warehouse and distribution points, and local area account manager, contact:

Magcobar Division, Dresser Industries, Inc.
Chem-Trete Operations
P.O. Box 6504, Houston, TX 77005
Call Toll Free: 800-231-1276
In Texas, call collect 713-784-8348
Telex: 762-349

10. FILING SYSTEMS

Spec-Data II

Additional literature available upon request.

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What to Expect

Practical performance tests of the Chem-Trete Silane surface

The critical factor in the durability of the water repellency conferred by Chem-Trete Silane is the durability of the Si-R bond. It is the hydrophobic character of the R-group which repels water from the masonry surface.

A number of measurements of new surfaces, formed by Chem-Trete Silane alteration of concrete and masonry, have been made. Tests show that a surface once treated exhibits totally different properties with respect to moisture than do natural surfaces. Tests were conducted by the Portland Cement Association (PCA).

Excellent performance as a coating base

A final coat of asphalt or paint is specified for many concrete surfaces. Tests were run to determine the effect of a Chem-Trete Silane application prior to laying down asphalt or painting.

Asphalt Adhesion Twelve 4-inch diameter by 8-inch high concrete cylinders were prepared and moist-cured for seven days. After six days of drying, six of the specimens were treated with Chem-Trete Silane. The specimens were allowed to dry for one additional day. Roofing asphalt plugs were then cast on the top of each cylinder. After seven days the plugs were sheared from the cylinder tops and shear strengths recorded.

Shear Strength, psi

	Avg.	Range
Coated Concrete	30.7	14.3-54.0
Uncoated Concrete	31.9	9.5-57.1

This indicates that treatment with Chem-Trete Silane prior to asphalt coating has a minimal effect on asphalt shear adhesion.

And as a paint base

Adhesion as measured using ASTM-D-3359-74 standard testing and measurement procedures on a treated and untreated concrete specimen.

	Adhesion Numbers		
Paint Type	Treated	Untreated	% Change
Acrylic	1-3/4	1-1/4	+40
Oil Base	2-3/4	2	+38
Epoxy	1-3/4	1-1/2	+17

In all cases, the adhesion of coatings was improved.

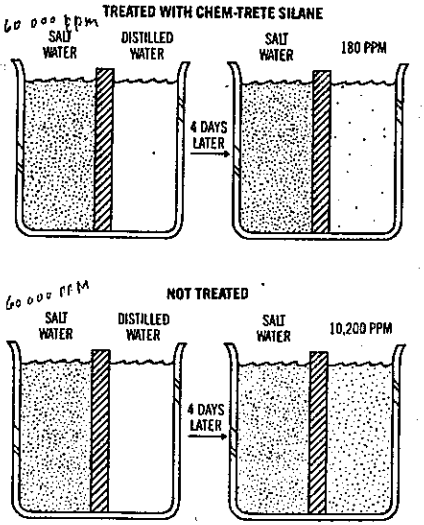
Chloride ion migration

Three cells were constructed. Each cell consisted of two reservoirs separated by a two-inch-diameter, 1/4-inch-thick disk of mature cement, having a water-cement ratio of 0.60 by weight. In each cell, the reservoir on the left was filled with 10% (60,000 ppm) NaCl, and the reservoir on the right was filled with distilled water. Two of the disks were treated by brushing Chem-Trete Silane lightly on one side. A third disk was left untreated.

The water on the right side of each cell was analyzed at the end of 4 days and the chloride ion content recorded as follows:

Cell No.	Chem-Trete Applied	Chloride Ion Content, Right Side
1	None	10,000 ppm
2	On side facing NaCl solution	180 ppm
3	On side facing distilled H_2O	1,440 ppm

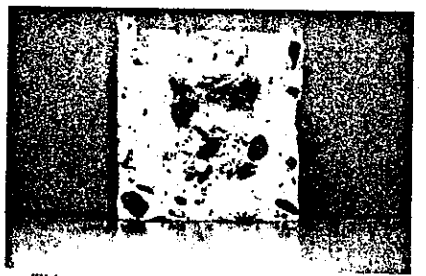
Common to all cells: 10% (60,000 ppm) NaCl solution on the left side, distilled water on the right. Chloride ion concentration determined on right side after four days.



Moisture absorption

Moisture absorption was measured by ASTM-C-642. Eight concrete cylinders, 3 x 3 inches, were cured and oven-dried according to test procedure. Four were treated with Chem-Trete Silane and four not treated. The cylinders were then submerged in water for 48 hours, followed by 24 hours submersion in boiling water. Six of the eight, three treated and three not treated, were then resubmerged in water. Two were broken for visual observation. Measurements on the percentage increase in weight were recorded as follows:

Submersion Time	% Weight Increase Treated	% Weight Increase Untreated
48 hours soak	0.8	4.8
24 hours boil	1.3	5.0
7 days	1.5	5.2
14 days	1.7	5.2
21 days	1.7	5.3
28 days	1.8	5.3
35 days	1.8	5.3
42 days	1.9	5.3
49 days	1.9	5.3
56 days	2.0	5.4



This concrete sample was broken after the moisture absorption test and dipped in water. Visual evidence of the depth of penetration of the Chem-Trete Silane is clearly indicated.

Reinforcement steel corrosion potential is dramatically reduced

Salt penetration annually causes serious economic loss because of corrosion of reinforcing bars in concrete highways, bridges and runways. Corrosion potential may be approximated by determining the electrical potential between a metal reinforcing member and the surface of a composite specimen.

Four blocks 12 x 12 x 8 inches with #4 reinforcing steel with 1/2 inch clear cover were fabricated. Two blocks were fabricated so that cracks were formed on the surface above the steel. One cracked and one not cracked were treated with Chem-Trete Silane.

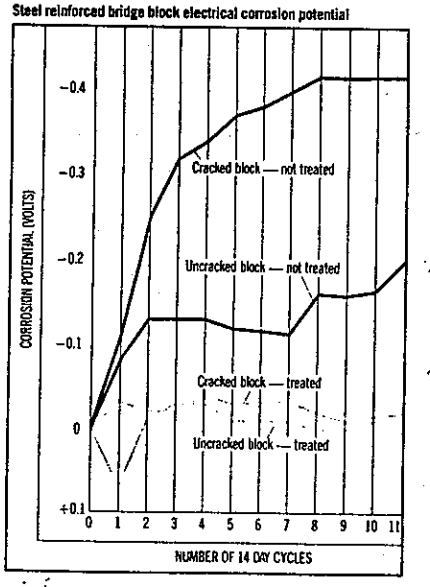
The four blocks were stored alternately for four days under 13.6% NaCl solution followed by 10 days drying. Electrical potentials between the steel and copper-copper sulfate half cells on the concrete surface were recorded every 14 days.

Intact Specimen	Treated (Volts)	Untreated (Volts)
1 Cycle	+0.07	−0.08
2 Cycles	−0.01	−0.13
3 Cycles	−0.03	−0.13
4 Cycles	−0.03	−0.13
5 Cycles	−0.01	−0.12
9 Cycles	−0.01	−0.16
13 Cycles	−0.05	−0.22
Cracked Specimen		
1 Cycle	−0.03	−0.11
2 Cycles	−0.02	−0.25
3 Cycles	−0.02	−0.32
4 Cycles	−0.04	−0.34
5 Cycles	−0.03	−0.37
9 Cycles	−0.02	−0.42
13 Cycles	−0.03	−0.43

Uncracked concrete specimens through 13 cycles of 14 days each under 13.6% NaCl solution. Each cycle consisted of 4 days soak + 10 days drying.

Results are summarized for specimens treated and untreated with Chem-Trete Silane in both cracked and intact concrete slabs. Under these test procedures, a potential of −0.3 volts generally indicates that the rebar has entered the active corrosion stage.

Steel reinforced bridge block electrical corrosion potential



APPENDIX B

Absorption Tests on Xypex, Chem-Trete, Conseal and Ma/Con

(Memo to file dated Dec. 1, 1978, by Ed Budney)

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State of California

Business and Transportation Agency

Memorandum

To : File

Date: December 1, 1978

File :

From : **DEPARTMENT OF TRANSPORTATION**
Office of Transportation Laboratory

Subject: Absorption Tests on Xypex, Chem-trete, Conseal, and Ma/Con.

PURPOSE

The purpose of this report is to evaluate the effectiveness of waterproofing agents by absorption tests.

MATERIALS

Product: Xypex
Manufacturer: Xypex Chemicals Ltd.
Waterproofing mechanism - Crystallization
Application rate: 1.5 lb - 5 part powder, 2 water
Cost:

Product: Chem-trete
Manufacturer: Dresser Industries, Inc.
Waterproofing mechanism - Chemical
Application rate: 400ft^2/gal. for porous stucco, 100ft^2/gal. for dense concrete.
Cost: $58.00/gal.

Product: Conseal
Manufacturer: Masonary Sealants Specialists, Inc.
Waterproofing mechanism - Fills voids with viscous gel.
Application rate: 100ft^2/gal.
Cost: $22.90/gal.

Product: Ma/Con
Manufacturer: Masonary Sealants Specialist, Inc.
Waterproofing mechanism - Fills pores with water resistant resin.
Application rate: 100 to 150ft^2/gal.
Cost: $23.90/gal.

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PROCEDURE

Tests roughly followed the procedure as outlined in the ASTM 642 absorption test. Tests used the following basic steps:

1. Specimens are oven dried for 24 hours at 170° F.
2. Cool and weigh specimens.
3. Apply waterproofing material.
4. Re-weigh specimens.
5. Place specimens in water bath at room temperature.
6. Weigh specimens at various times during soaking period.
7. Place specimens in boiling water for five hours, cool for 19 hours.
8. Weigh specimens.

Tests were conducted using two inch and three inch cubes. The two inch cubes were used in an ASTM C109 compressive strength test and had already been subjected to compressive failure. The three inch cubes were fabricated in the laboratory. Two mix designs were used, a 5 sack and a 7 sack mix using 3/4 inch maximum size aggregate. Cubes were cured in a fog room for seven days.

Chem-trete was tested using two inch cubes, subjected to three different conditions prior to being submerged in water. The first test followed the procedure as outlined earlier. Chem-trete was brushed on all surfaces of the specimens. After application, specimens were oven dried at 130° F for 24 hours, then submerged. Test 2 specimens were immediately submerged after the application of Chem-trete. Test 3 specimens were allowed to dry at 68° F, 50 percent relative humidity for 24 hours before being submerged. Chem-trete tests using three inch specimens followed the same procedure as Test 3 on the two inch specimens.

Xypex was tested using 7, two inch cubes. Specimens were dried for 24 hours, weighed and placed in a fog room for three hours. Xypex was prepared using 5 parts Xypex concentrate to 2 parts water. The paste was then brushed on the specimens and specimens were returned to fog room for six days. Cubes were then oven dried and submerged.

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Conseal was tested using the laboratory fabricated three inch cubes. Three variations of the basic test methods were employed. In first test, Conseal was applied to oven dried cubes, specimens were flushed with water after three hours, and submerged 24 hours after specimens were treated. In the second test, Conseal was applied to saturated specimens by manufacturer representatives. Conseal was sprayed on one side of the cube only. Three hours after the Conseal application, specimens were returned to the fog room for three days. Specimens were then oven dried and submerged. The third test consisted of applying Conseal to a specimen which had been soaking in water for 1 hour. After treatment the specimen was placed in a fog r ..m for four days, oven dried, and submerged.

Ma/Con was sprayed on oven dried three inch specimens by manufacturer representatives. Specimens were allowed to dry at 68° F and 50 percent relative humidity for 24 hours, then submerged.

RESULTS

Figures 1, 2, 3, and the Summary of Results (attached) illustrate the effectiveness of Chem-trete under different condtions. The specimens which were oven dried gained 0.4 percent weight after 24 hours of soaking. Specimens which were dried at room temperature prior to being submerged gained 1.30 percent weight after 24 hours, and specimens which were immediately immersed gained 4.70 percent weight after 24 hours. Thus, elevated temperature enhances the waterproofing ability of Chem-trete while specimens subjected to water after Chem-trete application show a decrease in waterproofing ability. Application amount corresponding to the 2 inch specimens was 100ft^2/gal. This amount seemed low, since manufacturer claims coverage of 100ft^2/gal. for porous stucco, and 400ft^2/gal. for dense concrete. Upon completion of the test, specimens treated with Chem-trete were broken. Cross sections revealed a wet spot in the center of the cube, surrounded by dry material about 5/8 of an inch thick. Three inch specimens treated with Chem-trete showed a weight increase of 0.35 percent and 0.50 percent for 5 sack and 7 sack mixes, respectively, after 24 hours of soaking. Application amount corresponding to these tests were 100ft^2/gal. for the 5 sack specimens and 170ft^2/gal. for the 7 sack specimens. After the test was completed three inch specimens were broken.

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Cubes treated with Chem-trete revealed a completely dry cross section. Wetting the cross section, showed Chem-trete to have penetrated an average of 3/8 inch for the 5 sack mix and 1/4 inch for the 7 sack mix.

Xypex treated specimens showed a weight increase of 7.5 percent in 24 hours compared to a weight increase of 8.5 percent in 24 hours for the standard specimens. Specimens broken after test completion revealed the cross section to be completely wet.

Conceal was applied to oven dried, saturated, and moist specimens Tests indicated a weight increase of 5.20 percent for both 5 sack and 7 sack specimens which were oven dried. Specimens saturated at the time application showed a weight increase of 6.78 percent and 6.42 percent for the 5 sack and 7 sack mixes, respectively, after 24 hours of soaking. The moist sample tested showed a 4.82 percent weight increase after 24 hours of soaking. Samples which had two coats applied showed about the same absorption rate. Broken treated cubes revealed a wet cross section. Application rates of Conseal were $137ft^2/gal$. for 5 sack specimens and $188ft^2/gal$ for 7 sack specimens.

Ma/Con was applied to specimens by manufacturer representatives. After 24 hours of soaking, specimens showed a weight increase of 2.75 percent and 2.45 percent for the 5 sack and 7 sack mixes respectively. After the test was completed Ma/Con treated cubes were re-dried for 24 hours at 170° F, cooled and submerged. Specimens showed a weight increase of 6.42 percent and 6.05 percent for the 5 sack and 7 sack specimens respectively after 24 hours of soaking. Broken specimens treated with Ma/Con revealed a wet cross section.

CONCLUSIONS

1. Under the conditions used in this experiment, Conseal and Xypex both proved ineffective as waterproofing agents.

2. Ma/con showed some promise as a waterproofing compound with a 2.5 percent weight increase after 24 hours of soaking. However after redrying treated cubes, absorption jumped up to about 6 percent.

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3. Chem-trete gave the best results of all products tested although it is more expensive. Chem-trete proved more effective when applied to a warm, dry concrete, than damp concrete or concrete subjected to water shortly after Chem-trete application.

PROJECT COMPLETION

With the completion of this report, this project has been terminated. The final cost of the project is $1,500.00.

ED BUDNEY
Roadbed and Concrete Branch

Attachment

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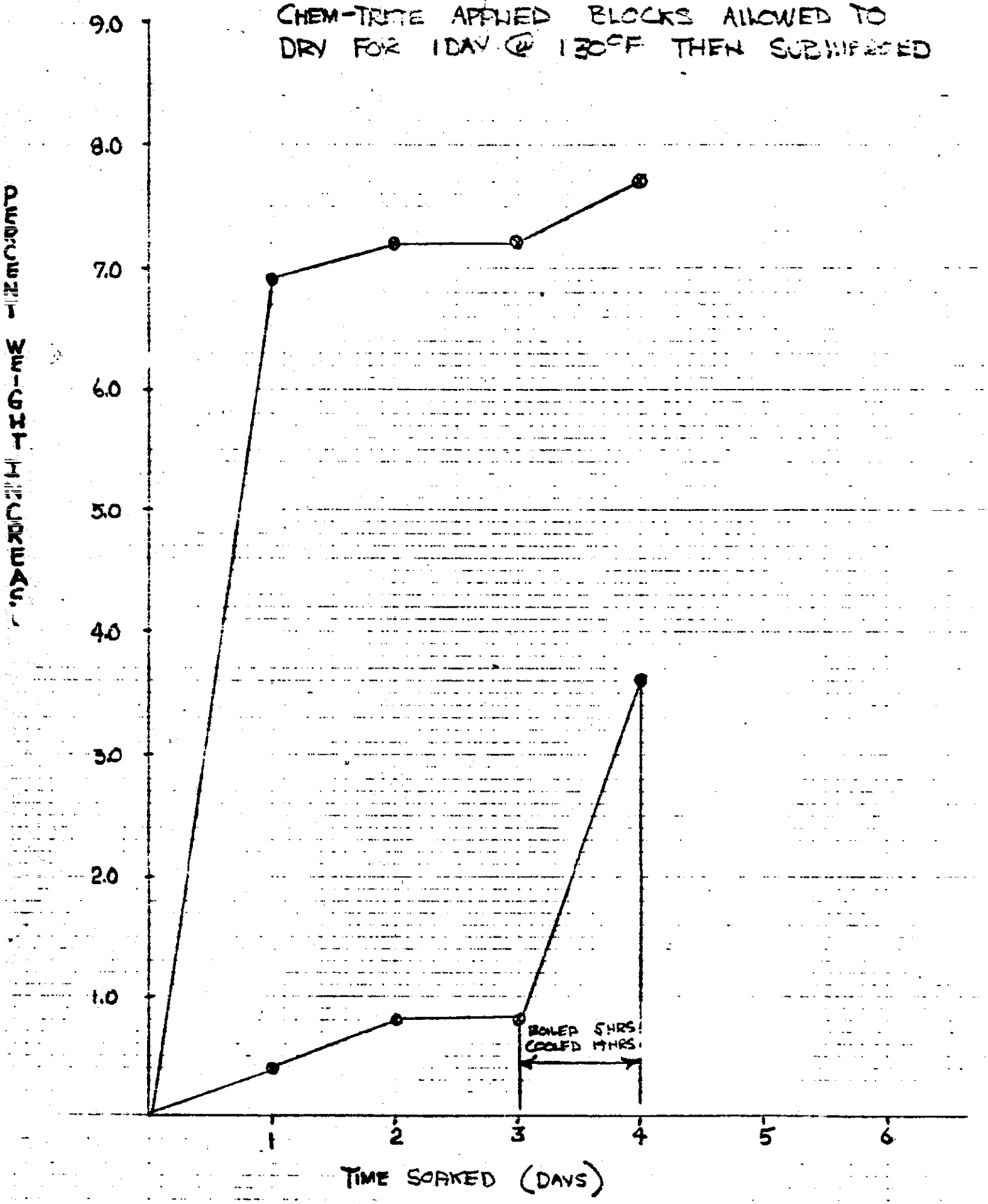

FIG. 1

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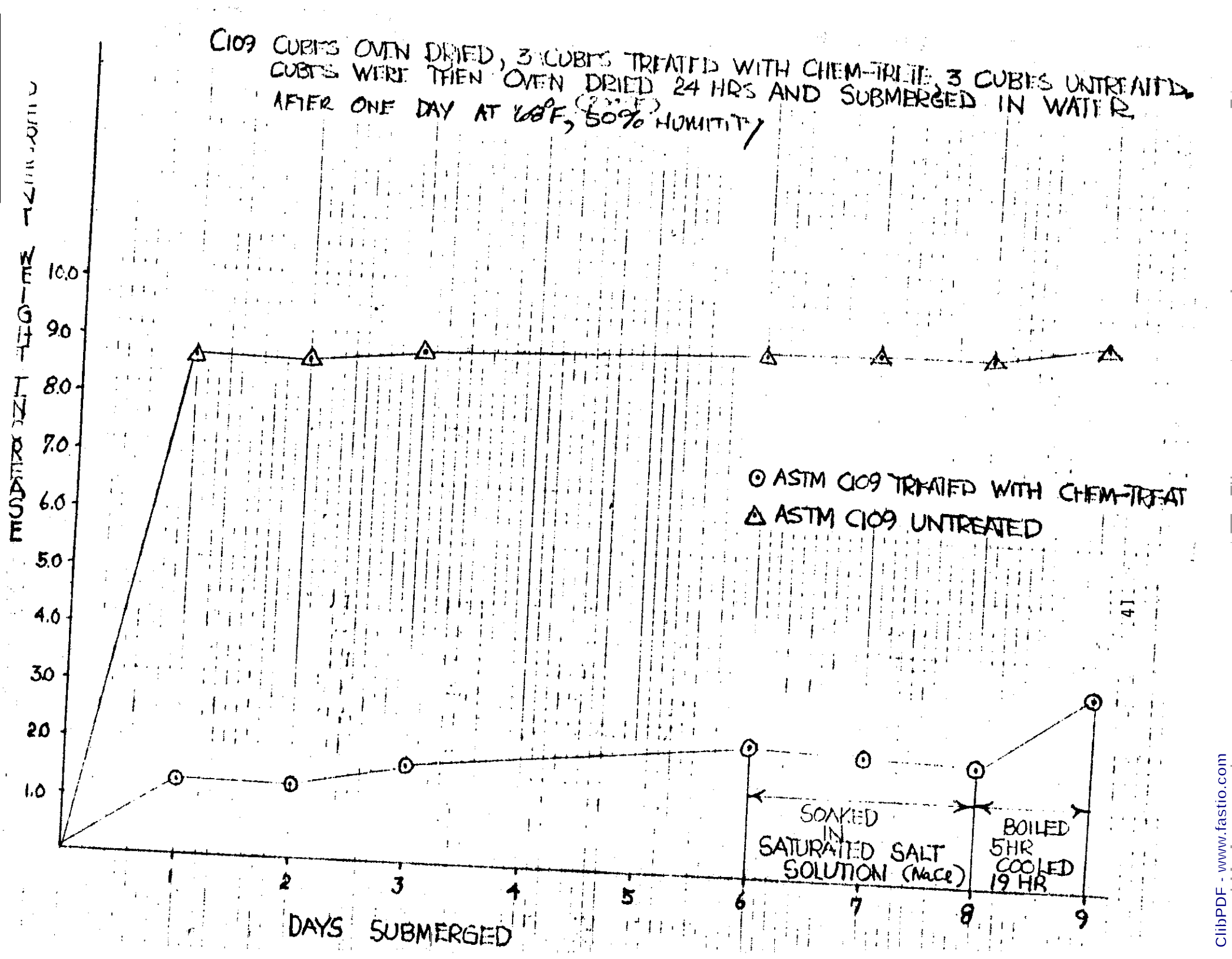
C109 CUBES OVEN DRIED, 3 CUBES TREATED WITH CHEM-TREAT, 3 CUBES UNTREATED. CUBES WERE THEN OVEN DRIED 24 HRS AND SUBMERGED IN WATER AFTER ONE DAY AT 68°F, 50% HUMIDITY



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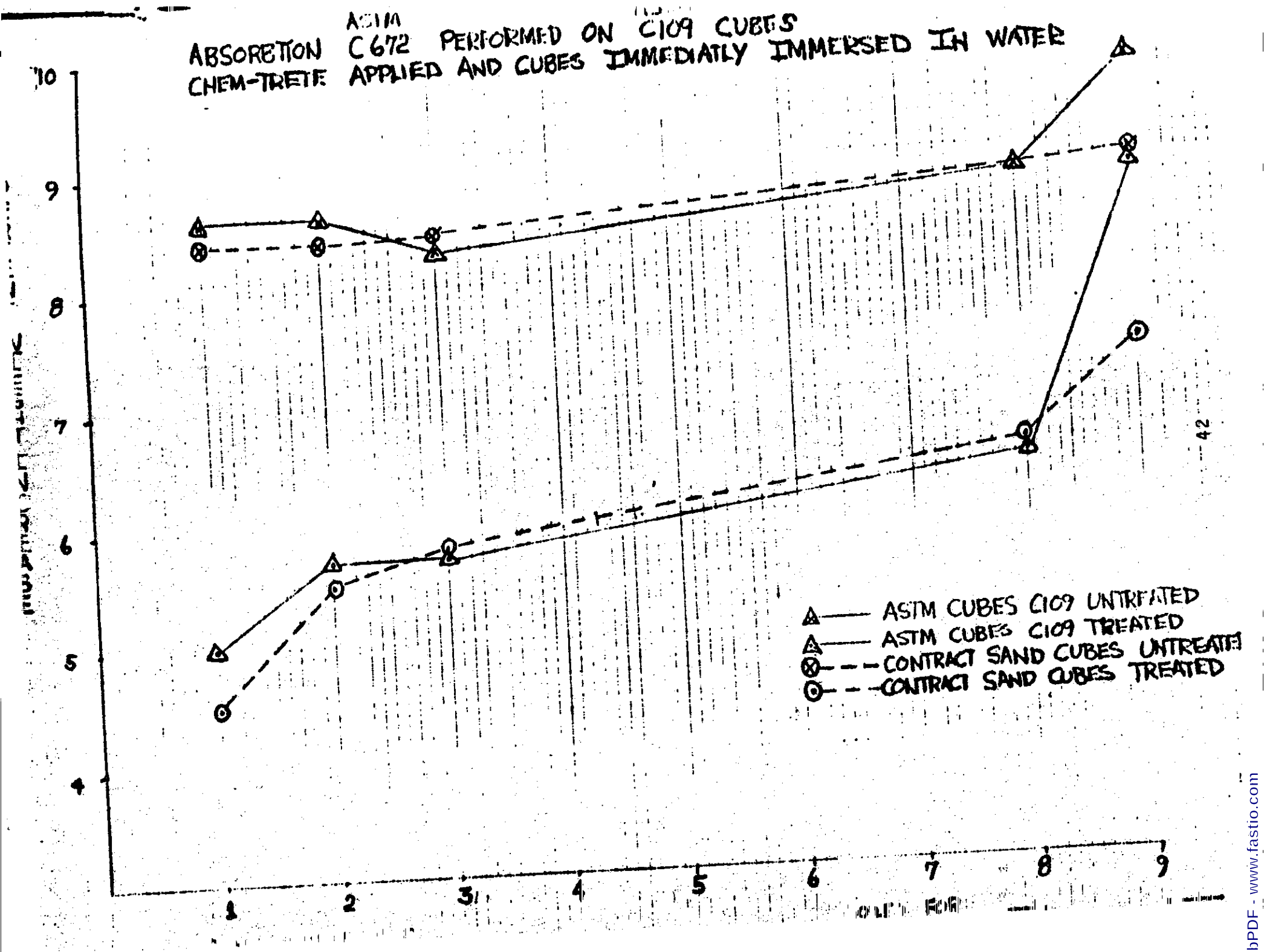

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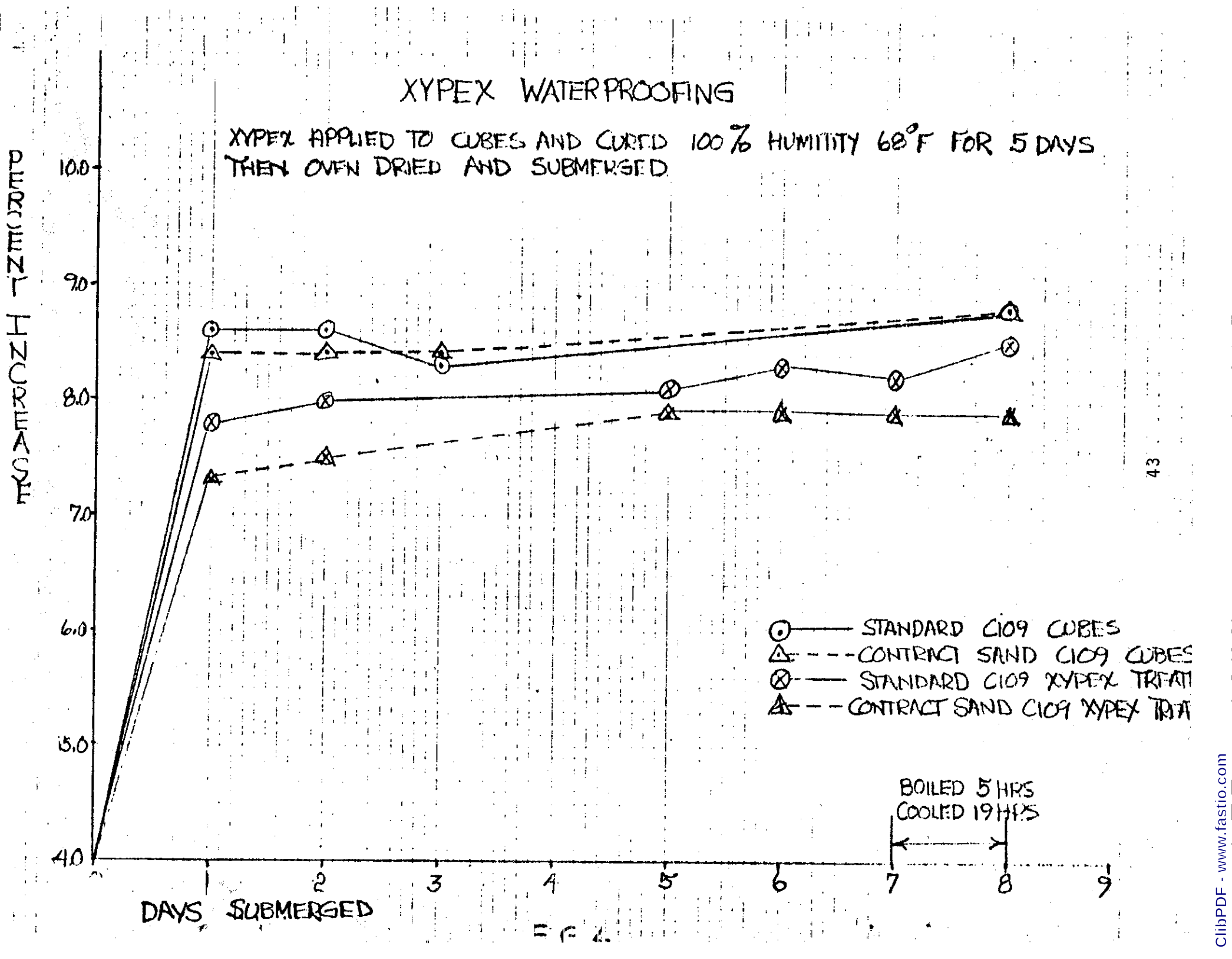

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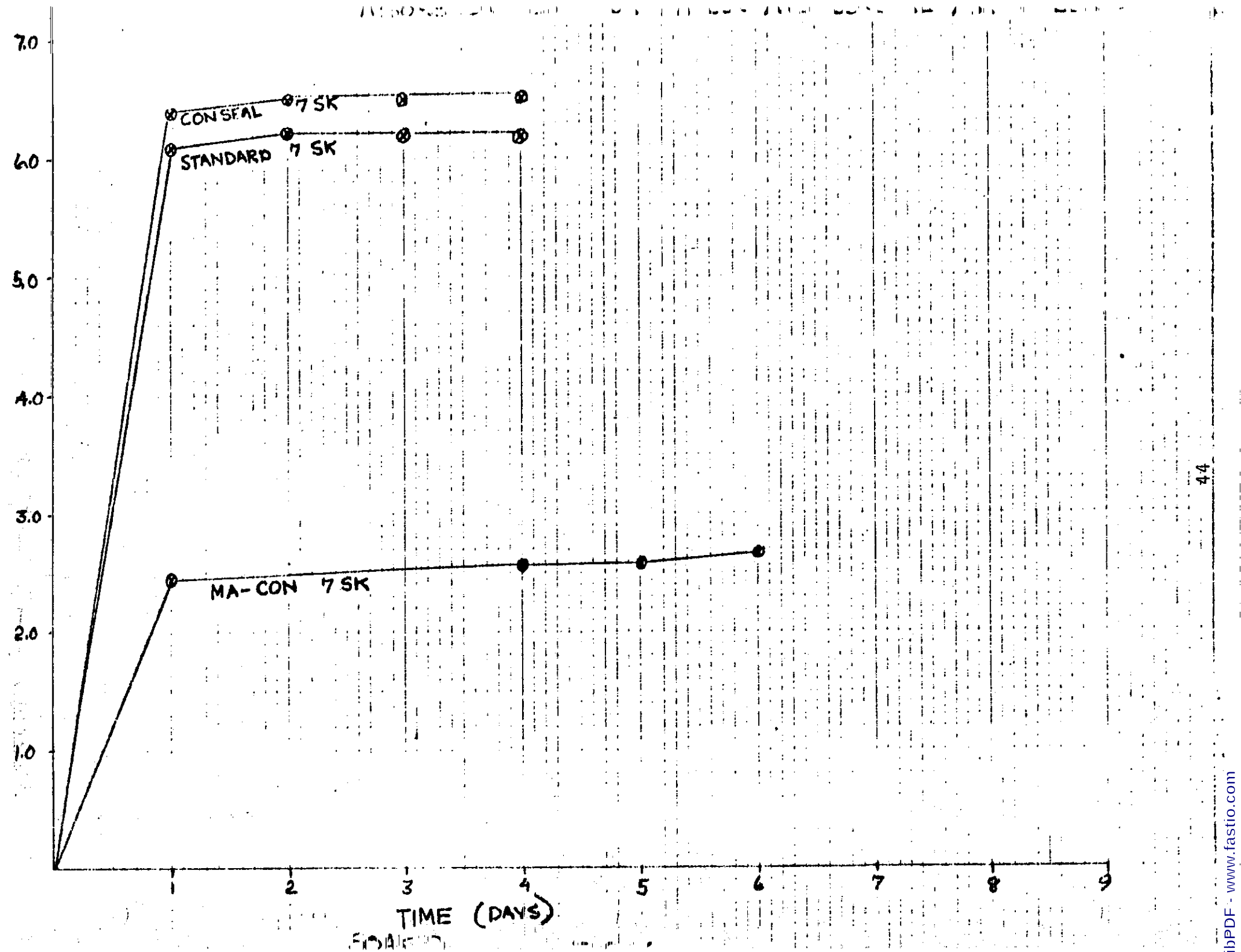

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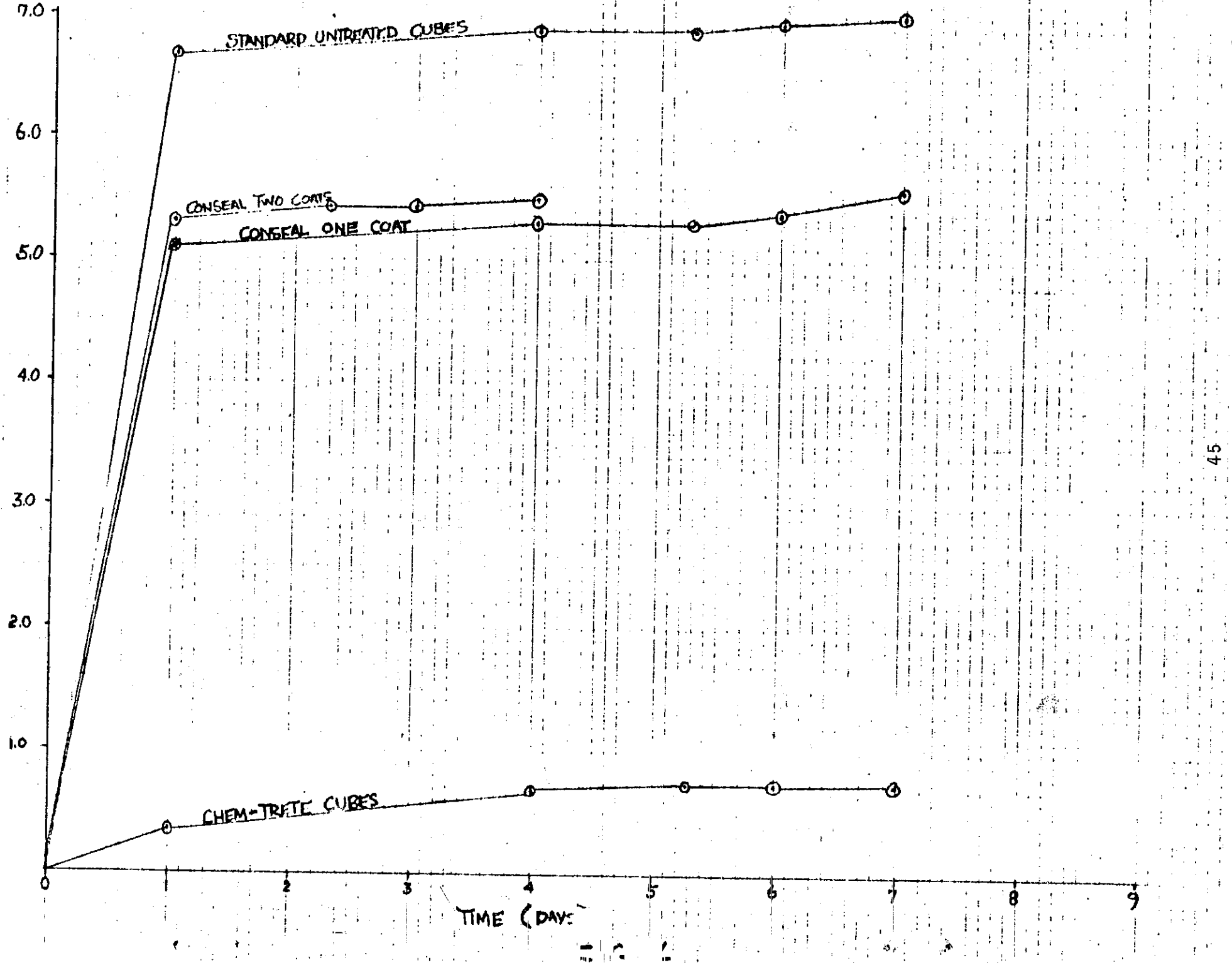

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SUMMARY OF RESULTS

MATERIAL TESTED	24 HR WT INCREASE TREATED	24 HR WT INCREASE UNTREATED
CHEM-TRETE APPLIED TO 2 INCH CUBES THEN OVEN DRIED	0.40 PERCENT	8.70 PERCENT
CHEM-TRETE APPLIED TO 2INCH CUBES THEN DRIED AT RM TEMP	1.30 PERCENT	8.70 PERCENT
CHEM-TRETE APPLIED TO 2INCH CUBES THEN SUBMERGED IN WATER	4.70 PERCENT	8.50 PERCENT
CHEM-TRETE APPLIED TO 5SK 3INCH CUBES	0.35 PERCENT	6.70 PERCENT
CHEM-TRETE APPLIED TO 7SK 3INCH CUBES	0.50 PERCENT	3.90 PERCENT
XYPEX APPLIED TO 2 INCH CUBES	7.50 PERCENT	8.50 PERCENT
MA/CON APPLIED TO 3INCH 5 SK CUBES	2.75 PERCENT	6.90 PERCENT
MA/CON APPLIED TO 3INCH 7 SK CUBES	2.45 PERCENT	6.40 PERCENT
MA/CON 3 INCH 7 SK CUBES REDRIED, SUBMER.	6.05 PERCENT	6.40 PERCENT
CONSEAL APPLIED TO DRY 7 SK 3 INCH CUBES	5.20 PERCENT	3.90 PERCENT
CONSEAL APPLIED TO SATURATED 5 SK 3INCH CUBES	6.78 PERCENT	6.90 PERCENT
CONSEAL APPLIED TO SATURATED 7 SK 3INCH CUBES	6.39 PERCENT	6.40 PERCENT
CONSEAL APPLIED TO DAMP 3INCH 7 SK CUBES	4.82 PERCENT	6.40 PERCENT
CONSEAL APPLIED TO DRY 5 SK 3 INCH CUBES	5.20 PERCENT	6.70 PERCENT

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APPENDIX C

Oklahoma Department of Transportation
Special Provisions for Experimental Penetration
Sealer System

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OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
BRIDGE DECK NON-EPOXY PENETRATING SEALER

These Special Provisions reivse, amend, and where in conflict, supersede applicable Sections of Standard Specifications for Highway Construction, Edition of 1976.

DESCRIPTION. This work shall consist of furnishing and placing a penetrating moisture proofing or moisture retarding system on a bridge deck in reasonable close conformity with the requirements specified herein and as shown on the Plans.

MATERIALS. The material shall be a non-epoxy penetrating sealer for Portland Cement concrete. The sealer must be able to reduce the moisture absorption of Portland Cement concrete to less than one percent (dry weight of the Portland Cement concrete laboratory specimens) when applied to a concrete surface in accordance with the manufacturer's recommendations and tested in accordance with the Oklahoma Department of Transportation 24 hours submerged absorption test for Portland Cement concrete moisture proofers and retarders. The sealer shall leave no residue, coating, or alter the Portland Cement Concrete surface where it will lower its skid resistance properties more than three BPN units when tested in accordance with ASTM Designation E 303-74.

The non-epoxy penetrating sealer shall be submitted for testing, prior to application, to the Materials Division of the Oklahoma Department of Transportation in Oklahoma City.

EQUIPMENT

(a) High Pressure Washer

CONSTRUCTION METHODS.

(a) Weather Limitations. The material shall not be applied when the air or surface temperature is less than 40°F, or while the surface is wet.

(b) Surface Preparation. The surface shall be cleaned to remove laitance, dirt, grease, asphalt, and other foreign materials, exposing a surface of sound concrete. Equipment shall be fitted with suitable traps, filters, drip-pans, or other devices to prevent oil or other deleterious matter from being deposited on the deck.

(c) Non-epoxy Penetrating Sealer. The non-epoxy penetrating sealer shall consist of one application and be applied at the rate recommended by the manufacturer.

METHOD OF MEASUREMENT. The sealer system will be measured by the square yard in place.

BASIS OF PAYMENT. The accepted quantities of sealer system will be paid for at the contract unit price for:

BRIDGE DECK NON-EPOXY PENETRATING SEALER SQ. YD.

which shall be in full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

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