

CertainTeed

Date

April 16, 1980

To

F. Niedergang

Location and mail code

BB 2126

Subject

Project 345 A/C Curing Investigation:
Double Autoclave at Plant 258

From

B. Jo *3/*

Location and mail code

BB 2126

cc: J. McGinley
H. Benhardt

PLAINTIFF'S EXHIBIT

CT-1475

Enclosed is an R&D report on the subject matter. It has proved that the double autoclaving improves the crush strength. The degree of crush strength improvement was known to be parallel with hydro strength improvement in the range of our interest.

However, it is not certain that the degree of improvement observed in this investigation is really critical for turning a batch of product from failure to passing the specification. Improvement by the double autoclave seems to be the result of the combined effect of wetting with water prior to double autoclave and the autoclave reaction. This raises a question as to whether the moisture content of the pipe prior to the 1st autoclave was sufficient. If not, water treatment prior to the 1st autoclave could eliminate the double autoclave.

BHJ/pha

RECEIVED APR 17 1980

*1) what rec. do we have to reduce the
need for double auto claving.*

CertainTeed	Date	To	Location and mail code
	April 7, 1980	Dr. B. Jo	BB #2126
Subject	PROJECT 345 A/C CURING INVESTIGATION	From <i>J. Malone</i> J.A. Malone/db	Location and mail code BB #2126

cc: Mr. F. Niedergang - BB #2126
 Mr. J.P. McGinley - VF P&PG #2B
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INVESTIGATORS:

John A. Malone
 John P. Ungerman
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OBJECTIVES:

To determine the increase in crushing strength resulting from "double autoclaving" at plant 258, using both the plant and the experimental shop autoclaves.

CONCLUSIONS:

- 1). "Double Autoclaving" produced about a 4.3 percent increase in average modulus of rupture in crush.
- 2). The samples autoclaved at the experimental shop were about 2.6 percent higher in crush modulus than those autoclaved at plant 258, making the results approximately equivalent.
- 3). A very good correlation exists between crush modulus and density.
- 4). Differential thermal analysis for tobermorite and unreacted silica tends to confirm an increase in strength with "double autoclaving".

PROJECT 345
-A/C CURING INVESTIGATION-

PLANS AND RECOMMENDATIONS:

- 1). Evaluation of "double autoclaving" in the laboratory under various precure, autoclaving, and wetting conditions.
- 2). Use of cements and silicas from the various asbestos-cement pipe plants in these laboratory studies.
- 3). Recommendations to the asbestos-cement pipe plants and quality control based on present and future test data.

KEY WORDS:

Asbestos-cement pipe, autoclaving, crushing strength, curing, manufacturing, tobermorite.

CURING INVESTIGATION

ASBESTOS-CEMENT

(DOUBLE AUTOCLAVING AT PLANT 258)

PROJECT 345

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APRIL 11, 1980

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INTRODUCTION:

- 1). Plant 258 has frequently found it necessary to "double autoclave" 6-inch and 8-inch pressure pipe in order to meet the specified strength requirements. This "double autoclaving" cycle is as follows:
 - (a) The pipe is autoclaved for 14 hours with saturated steam at 145 to 150 psig (usually within 2 to 8 hours after removal from the last precure tunnel). There is no rewetting of the pipe at this stage.
 - (b) The pipe is removed from the autoclave and cooled (this time varies up to several days depending on autoclave availability for the second cycle).
 - (c) The pipe is wet with water using a hose, and is then autoclaved for an additional four hours with steam at 145 to 150 psig.
 - (d) In all cases, the autoclave is charged and blown down over about a 45 to 60 minute period.

The present study was designed to determine the increase in crushing strength for 8"-150 pipe resulting from "double autoclaving" at plant 258, and from "double autoclaving" under similar conditions at the experimental shop in Blue Bell. The purpose of the Blue Bell study was to evaluate strength increase under carefully controlled conditions for comparison with plant practice.

EXPERIMENTAL METHODS:

- 1). Two 8"-150 pipe were selected and marked before entering the first precure tunnel so as to be certain that they had identical treatment at rollup, breaking, and calendering.
- 2). At the end of the second precure tunnel, these two pipes were removed, cut and the pieces identified as indicated in Figure 1. The first six inches were discarded for both pipe.

3). The "L" samples were sent to Blue Bell for autoclaving in the Experimental Shop; the "P" samples were autoclaved at plant 258 together with the regular production from which they were selected.

4). The following autoclaving cycles were followed at the two locations:

(a) Plant 258

The procedure listed in (a) thru (d) under INTRODUCTION was followed at plant 258.

All the "P" samples were autoclaved for 14 hours; only the P_4 , P_5 and P_6 samples were autoclaved for the additional four hour period. (The time after removal from the second tunnel until the start of pressure build up for the first autoclaving cycle was 6 hours; the time after blow down until the start of pressure build up for the second autoclaving cycle was three days).

It should be noted that the P_A and P_B sections from Pipe 1, and the P_C and P_D sections from Pipe 2 were used for control purposes.

(b) Experimental Shop

The same procedure was followed relative to scheduling and autoclaving conditions in the Experimental Shop as at plant 258. All the "L" samples were autoclaved for 14 hours; only the L_4 , L_5 and L_6 samples were autoclaved for the additional four hour period.

5). After autoclaving was complete, one-inch rings were cut from each of the 13-inch samples, as indicated in Figure I, for density determinations. All samples were held at room conditions in the Experimental Shop for approximately five days prior to test.

6). The following tests were then run in accordance with the procedures indicated:

(a) Crushing Strength

Standard Wood Block Crush

Test according to ASTM Method C500-77, entitled Standard Methods of Testing Asbestos-Cement Pipe.

The modulus of rupture in crush was calculated as follows:

$$MR = \frac{(0.955)(ID + t_B)(P)}{(12)(t_B)^2}$$

WHERE

MR = Modulus of Rupture - lbs./sq.in.

ID = Inside Diameter-inches

t_B = Thickness at break-inches

P = Crush load-pounds/foot

12 = inches/foot

0.955 = constant

(b) Density

CertainTeed Technical Specification TM-5, entitled Water Displacement Density Test Method for A/C Products.

RESULTS:

TABLE I - CRUSHING STRENGTH

<u>Sample</u>	<u>Crush Load lbs./ft.</u>	<u>Thickness at break t_B-inches</u>	<u>ID + t_B inches</u>	<u>Modulus of Rupture lb./sq.inches</u>
P ₁	5329	0.780	8.683	6053
P ₂	7004	0.833	8.740	7021
P ₃	6560	0.828	8.752	6665
L ₁	6854	0.825	8.729	6996
L ₂	6848	0.837	8.754	6810
L ₃	6414	0.818	8.720	6652
P ₄	7368	0.833	8.747	7392
P ₅	7133	0.828	8.800	7286
P ₆	7065	0.818	8.773	7372
L ₄	6522	0.810	8.694	6878
L ₅	7770	0.830	8.792	7892
L ₆	7460	0.828	8.784	7607
P _A	6384	0.800	8.698	6905
P _B	6360	0.830	8.744	6424
P _C	6747	0.823	8.717	6910
P _D	6596	0.833	8.770	6635

TABLE II - DENSITY

<u>SAMPLE</u>	<u>PIPE SECTION</u>	<u>DENSITY lb./cu.in.</u>
D ₁	P ₁	0.0626
D ₂	P ₂	0.0633
D ₆	P ₆	0.0646
D ₃	L ₃	0.0627
D ₄	L ₄	0.0635
D ₅	L ₅	0.0644
	AVERAGE	0.0635

TABLE III - DIFFERENTIAL THERMAL ANALYSIS (DTA)

<u>Sample</u>	<u>Modulus of rupture lbs./sq.in.</u>	<u>Tobermorite Exotherm (area-in.² x 100)</u>	<u>Unreacted SiO₂ Endotherm (area-in.² x 100)</u>
L ₁	6996	310.8	7.0
P ₂	7021	320.0	7.8
Average	7009	315.4	7.4
L ₅	7892	336.0	7.5
P ₄	7392	313.0	6.5
Average	7642	324.5	7.0

NOTE: L₁ and P₂ samples were "single autoclaved".

L₅ and P₄ samples were "double autoclaved".

DTA diagrams obtained with Delta Therm Model D2000 apparatus at a heating rate of 10°C per minute, using left oven with #1 sample holder. All results are an average of four sample tests.

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SAMPLE LOCATION IN PIPE

AND TEST RESULTS

		P ₁	D ₁	P _A	L ₁	P _B	P ₂	D ₂	L ₂	P ₃	L ₃	D ₃
PIPE	A	5329	.0626	6384	6854	6360	7004	.0633	6848	6560	6414	.0637
1.	B	6053	.0625	6905	6996	6424	7021	.0631	6810	6665	6652	.0637

		L ₄	D ₄	P _C	P ₄	P _D	L ₅	P ₅	P ₅	L ₆	P ₆	D ₆
PIPE	A	6522	.0635	6747	7368	6596	7770	.0644	7133	7460	7065	.0646
2	B	6878	.0635	6910	7392	6635	7892	.0644	7286	7607	7372	.0646

"A" - CRUSH STRENGTH - LB./FT.

"B" - MODULUS OF RUPTURE IN CRUSH LB./IN.²

D - DENSITY RING & DENSITY

FIGURE I

DISCUSSION:

- 1). There was an increase in crush modulus due to "double autoclaving" at the plant of about 10.1 percent, and at the shop of about 7.8 percent for an average of 9.0

In arriving at this figure, an average difference of 108 pounds per square inch between the control samples from Pipe I (6665) and those from Pipe 2 (6773) was applied in the calculation. Further, it should be noted that a significant strength difference due to position existed in both pipe (see Figure I), thus tending to overshadow the results.

- 2). Another consideration is the density difference between Pipe 1 and Pipe 2 (0.0630 to 0.0646 for the plant samples, and 0.0627 to 0.0640 for the shop samples). Since strength is roughly proportional to the density squared, this could account for about 5.1 percent of the plant increase, and about 4.2 percent of the shop increase for an average of 4.7 out of the 9.0 previously calculated for "double autoclaving".

only for density increase

- 3). It should also be noted that the difference in crush modulus for the shop samples averaged about 2.6 percent higher than that for the plant samples.
- 4). Based on the foregoing considerations, the increase in crush strength due to "double autoclaving" alone averages about 4.3 percent. Further, the results obtained with the plant and the shop autoclaves are approximately equivalent.
- 5). As indicated in Table III, the increase in strength resulting from "double autoclaving" is accompanied by the expected increase in tobermorite content and decrease in unreacted silica.

RECOMMENDATIONS:

It is considered that the effect of "double autoclaving" should be studied in more detail in the laboratory under various precure, autoclaving, and wetting conditions, using cements and silicas from the various asbestos-cement pipe plants. A recommendation to this effect has been included in the proposed study entitled Asbestos-Cement Curing Investigation (Project 345).