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EXAMINATION OF TWO PIECES OF A SPLIT PILE FROM THE FERRY TERMINAL WHARF AT CARIBOU, NOVA SCOTIA

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Samples of a steel sheet pile which had split longitudinally, were examined metallurgically. It was found that the material was excessively dirty, the tearing type of failure being associated with a heavy lamination of non-metallic inclusions.

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INTRODUCTION

Two pieces of a split steel sheet pile were received from the Department of Public Works. A covering letter dated October 13, 1960 (File No. 1362-66), stated that the sections of split pile were removed from the Ferry Terminal Wharf at Caribou, Nova Scotia. The pile from which the samples have been taken, had been examined by Dr. W.A. Morgan in November of 1959 and, at that time, it was requested that a piece of the failed pile be forwarded to this Department for detailed analysis.

VISUAL EXAMINATION

Visual examination showed that the pile had failed at the radius of the flange and web junction, tearing in a longitudinal direction (Figure 1). Although both surfaces of the fracture were severely corroded, it was quite evident that a fibrous type of fracture had occurred.

CHEMICAL ANALYSIS

Chemical and spectrographic analyses of the samples submitted were carried out. Table 1 gives the chemical requirements of the Department of Public Works specification, and the Mines Branch chemical and spectrographic results.

TABLE 1

Results of Mines Branch Chemical and Spectrographic Analysis

Elements	Specified Check Analysis %	Mines Branch Chemical Analysis %	Mines Branch Spectrographic Analysis %
Carbon	0.34 max	0.17	-
Manganese	0.89 max	0.37	-
Silicon	0.13-0.33	0.18	-
Sulphur	0.063 max	0.037	-
Phosphorus	Acid 0.075 max Basic 0.050 max	0.032	-
Nitrogen	-	0.013	-
Aluminum	-	0.02	0.03
Chromium	-	0.06	0.07
Copper	-	0.015	0.03
Nickel	-	0.03	0.07
Molybdenum	-	-	<0.01

MACRO ETCH

Transverse slices were etched in 1:1 HCl and water at 160° to 170°F (70°C to 75°C) for ten minutes. The samples were uniformly etched and showed no indication of segregation (Figure 2).

TENSILE TESTS

Transverse and longitudinal full thickness tensile bars having a 2 in. gauge length were obtained from the samples received, the bars being taken from the web and flange section, respectively. All bars tested showed a laminated type fracture, the lamination effect being greatest in the transverse bars (Figure 3).

The results of these tests are given in Table 2.

TABLE 2

Results of Tensile Tests

Bar No.	Location	Orientation	Ultimate Strength kpsi	Yield Point kpsi	% El. in 2 in.
Mechanical Test Specification	-	-	60.0	33.0	21% in 8 in.
1	Flange	Longitudinal	68.0	49.1	29
2	Flange	Longitudinal	71.6	58.4	32
3	Web	Transverse	66.0	45.2	17.0
4	Web	Transverse	66.0	42.8	20.0

IMPACT TESTS

From the web section, longitudinal Charpy V-notch impact bars, notched 90 deg to the plate surface were machined. Tests were carried out at each of the following temperatures -18, 0, 20, 30, 65 and 100°C (0, 32, 72, 100, 150 and 212°F), three bars being tested at each temperature. The results of these tests were scattered. However, the samples could be separated into two groups by the appearance of the fractures, fibrous plus crystalline or laminated plus crystalline (Figure 4). The results were grouped according to the fracture appearance of the bars and a graph was prepared showing the difference in impact values at each testing temperature (Figure 5). Table 3 gives the results of the impact tests and the 15 ft-lb transition temperatures taken from the graph in Figure 5.

TABLE 3

Impact Results According to Fracture Appearance

Temp. Tested °F	Energy Absorbed ft-lb		15 ft-lb Transition Temp. °F	
	Fibrous + Cryst.	Laminated + Cryst.	Fibrous + Cryst.	Laminated + Cryst.
0	23.5	12	Below 0°F	32°F
32	34.0	14		
72	45.0	18		
100	44.0	17.5		
150	46.0	17		
212	43.0	-		

SPECTROGRAPHIC TRAVERSE

To determine if chemical segregation could account for the variation in impact results and fracture appearance, a half section of two Charpy impact bars was selected to represent fibrous and laminated type of fractures. These samples were diagonally sectioned and prepared for a spectrographic traverse. The samples were divided into 3 zones, A-fibrous and crystalline or laminated and crystalline, B-fibrous or laminated, C-crystalline. Two traverses were made on each sample from A to B and from C to B, starting at about 1 mm from each end and overlapping in the centre (Figure 6). The spectra were analyzed for nickel, chromium, aluminum, copper, silicon and manganese.

Both samples gave similar results and were reported as follows:

Nickel - trace

Chromium - not detected

Copper - present, but no segregation.

Aluminum, silicon and manganese were segregated as follows:

Aluminum was present in only very small amounts (trace) at ends A and C. There was a marked increase in the region B. The fall-off of the intensities of the aluminum lines corresponded with the boundaries of the fracture regions marked on the specimens.

Segregation of silicon and manganese was not so marked as aluminum.

The amount of silicon was highest in the region B and lower in region C than in A. The segregation of manganese was similar to that of silicon but less marked.

Both samples contained numerous inclusions. Where the spark crossed these, small high intensity "blips" were made on the lines of aluminum and silicon. These "blips" are superimposed on the overall variation of the aluminum and silicon and may help to account for the higher concentration of silicon in region B over region A. However, they do not appear to be entirely responsible for the large variation in aluminum content, nor for the fall in concentration of silicon and manganese in region C.

MICRO-EXAMINATION

The opposite halves of the Charpy impact bars used for spectrographic traverse, were prepared for micro-examination of the fractured surface. In the as-polished condition both samples were dirty, the concentration of inclusions being heaviest in the areas of fibrous and laminated type fracture, and could account for a large part of the chemical segregation. Etched in nital the samples revealed a normal ferrite-pearlite structure, with a uniform grain size in all areas. The only difference noted between the two samples was in the size and distribution of inclusions, the sample showing a fibrous type of fracture having the largest and heaviest concentration. Figure 7 shows the distribution of inclusions and the micro-structure found in the various regions.

DISCUSSION

No defects were found to indicate that the failure of the pile had originated in the area submitted for examination. Chemical analysis of the material shows it to be within the Department of Public Works chemical requirements for steel sheet piling; the high nitrogen content however is undesirable. All tensile tests have met the specifications as to the ultimate and yield strength but the transverse bars have failed to meet the specified elongation. Fractures of the transverse tensile and some of the impact specimens show a heavy lamination. Longitudinal tensile bars also show laminations but to a lesser degree. Impact test bars fractured with two distinct types of fractures, laminated and fibrous, each type of fracture giving different impact values for any given temperature. The 15 ft-lb transition temperatures obtained from these tests are of little value as the effect of the lamination of inclusions cannot be evaluated. Spectrographic traverses have revealed chemical segregation of three elements; microscopic examination shows a heavy concentration of inclusions in the segregated areas, the size and amount affecting the type of fracture and impact values obtained. Although no positive identification of the inclusions has been made, it would seem that they do account for a large part of the chemical segregation.

CONCLUSIONS

1. The material examined is excessively dirty.
2. Heavy lamination of non-metallic inclusions has been responsible for the tearing type of fracture.

Figure 1. Samples as-received.
1/5 actual size.

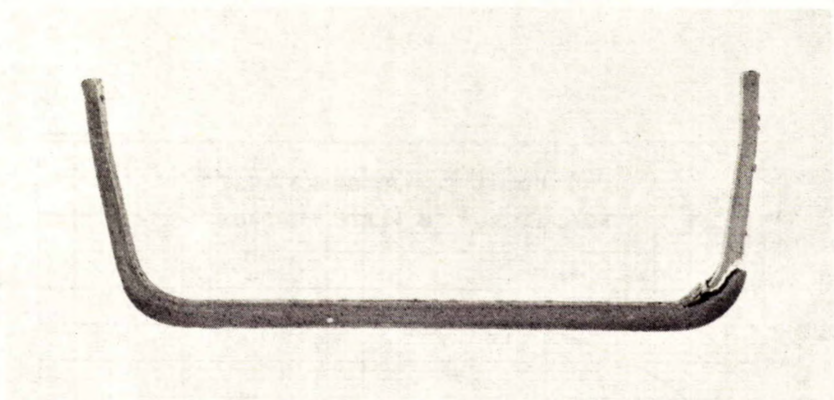
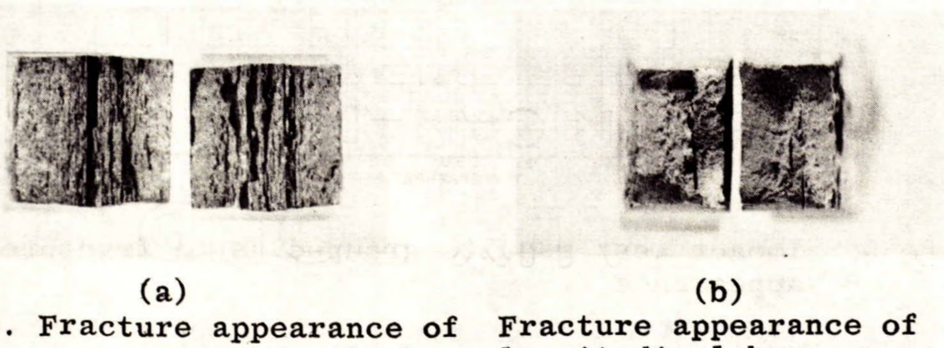


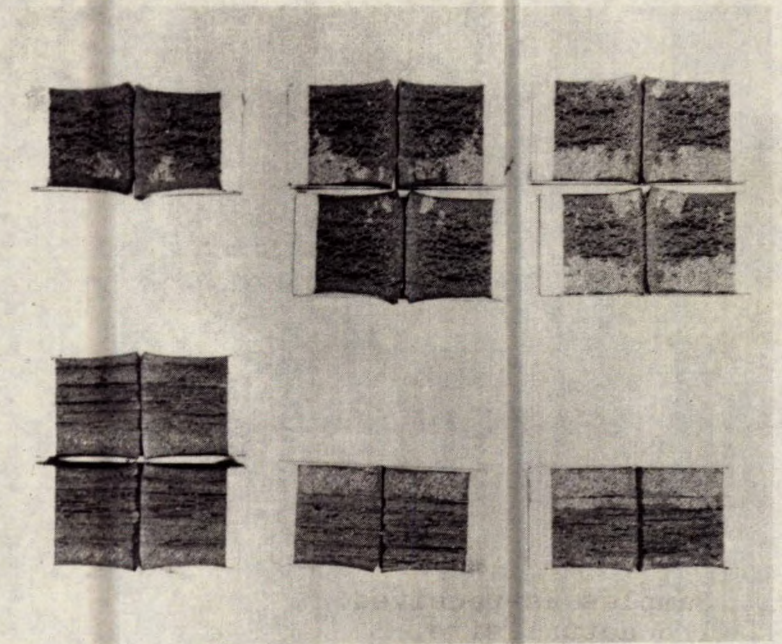
Figure 2. Etched in 1:1 HCl and water for ten minutes.



(a) (b)

Figure 3. (a) Fracture appearance of transverse tensile bars. $1\frac{1}{2}$X actual size

(b) Fracture appearance of longitudinal bars. 2X actual size.



Fibrous + crystalline type fracture.

Laminated + crystalline type fracture.

Figure 4. Impact test specimens grouped as to type of fracture.

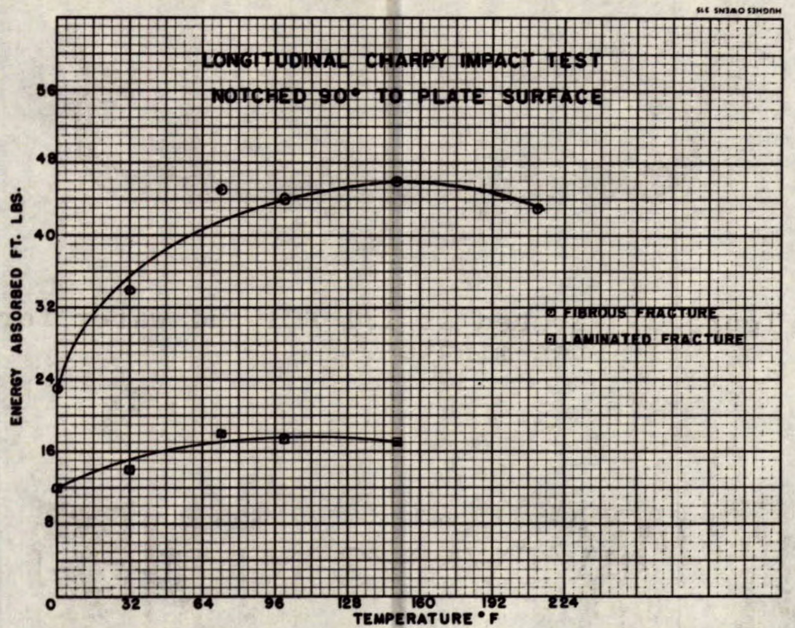


Figure 5. Impact test results grouped as to fracture appearance.

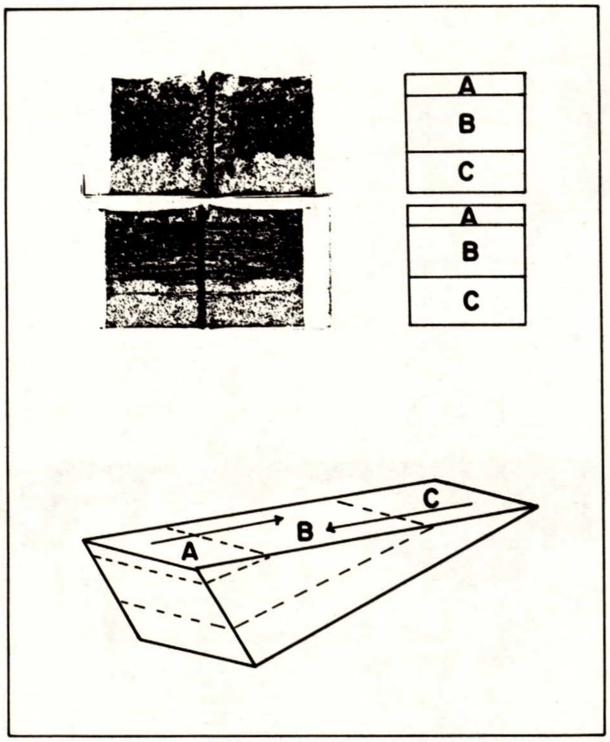


Figure 6. Zones of Spectrographic Traverse Samples.

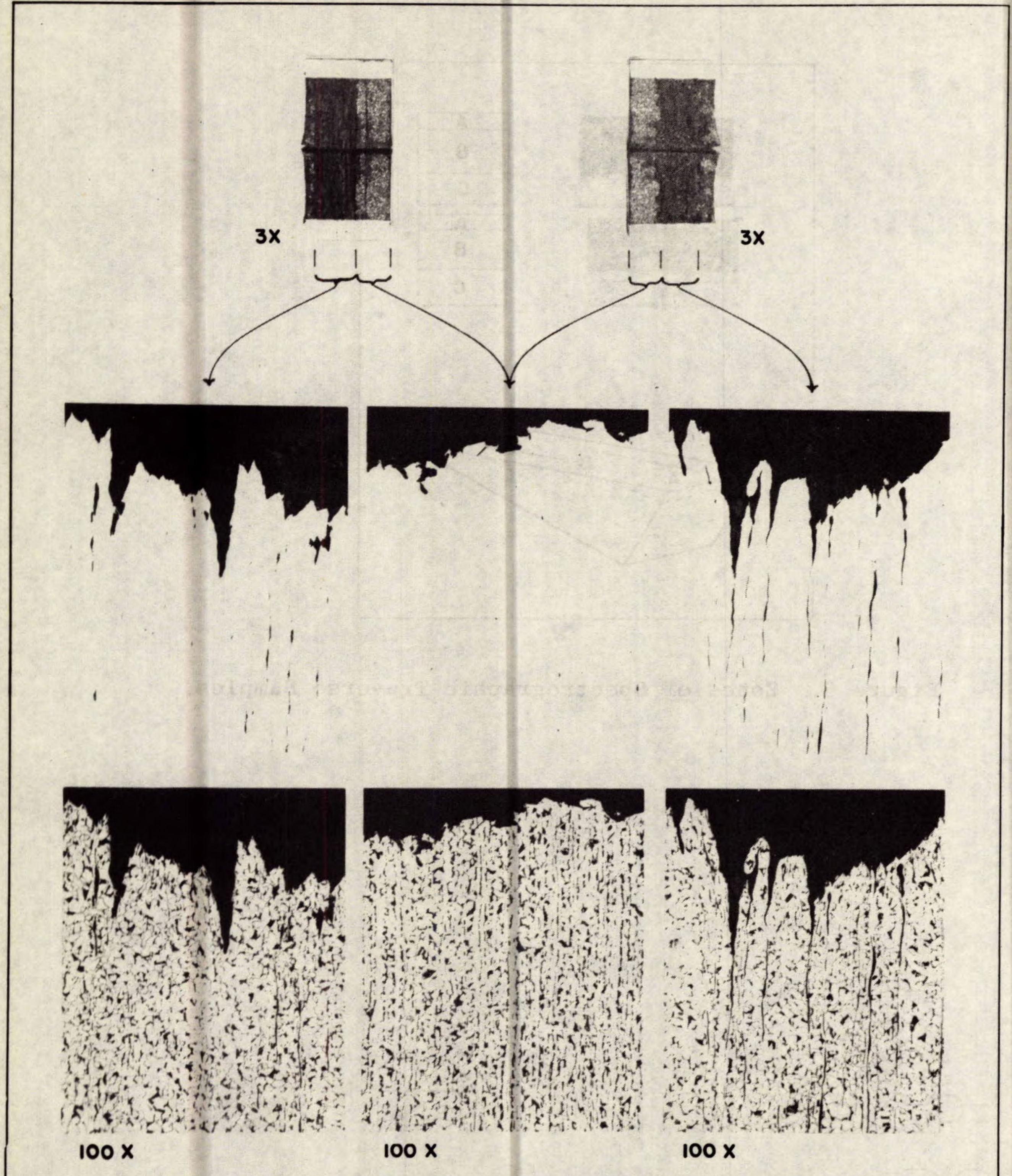


Figure 7. Distribution of inclusions and micro-structure at the various regions of impact specimens. 1/2X actual size.