Director, Mines Branch

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 58-35

SECOND REPORT ON EVALUATION OF THE PROPERTIES OF HIGH TENSILE STEEL SHEET PILING (LARSSEN III) FOR USE AT COMEAUVILLE, N. S.

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Examination of two additional samples confirmed the findings on the original sample reported in Investigation Report No. PM3245, i. e. that this material cannot be categorically condemned for the projected use but that the probability of failure in service is high.

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INTRODUCTION

In October 1957, Mr. J. W. Lucas, Chief, Testing Laboratories, Development Engineering Branch, Department of Public Works, Ottawa, Ontario, submitted to the Mines Branch one sample of high tensile steel sheet piling for evaluation. This was reported on in Investigation Report No. PM3245, dated November 18, 1957. The suitability of the material for the application was considered somewhat dubious. Also, one piece was not considered an adequate sample to represent the total quantity of material involved.

Accordingly, two further samples were forwarded to the Physical Metallurgy Division by Mr. Lucas (with letter, File 32-687-M) on January 15, 1958. These samples, identified hereinafter as Comeauville Piles 2 and 3, were examined in essentially the same manner as the first sample (Pile 1) received. Data from the first report are incorporated in the present report.

CHEMICAL ANALYSIS

Material for analysis was drilled at points between the centre of the web and the outer end of the interlock. The aluminium content was determined by semi-quantitative spectrographic analysis. The other elements were determined by chemical analysis. Results are as given below in Table 1.

TABLE 1. - Chemical Analysis of Steel Sheet Piling Samples 1, 2 and 3.

Element	PILE NO. 1	PILE NO. 2	PILE NO. 3	Specification
	%	%	%	
Carbon	0.36	0.21	0.21	0.25 max
Manganese	0.88	0.54	0.55	0.70 - 1.00
Silicon	0.12	0.09	0.11	0.15 - 0.25
Sulphur	0.041	0.040	0.047	0.05 max
Phosphorus	0.062	0.053	0.056	0.05 max
Copper	0.03	0.01	0.01	0.37 - 0.80
Chromium	0.02	0.02	0.02	0.60 max
Nickel	0.10	0.09	0.10	-
Aluminium	0.008	0.005	0.004	-
Nitrogen	0.014	0.012	0.012	-

MACROSTRUCTURE

Full sections were deep etched in hot 1:1 HCl and water for 10 minutes. Sulphur prints were taken from other full sections. No abnormal piping or segregations were noted.

MICROSTRUCTURE

Longitudinal sections from the centre of the web and from the outer bend of the interlock were examined. As with Pile 1 the material was dirtier at the centre than at the interlock. However, in general, Piles 2 and 3 were somewhat cleaner than Pile 1 (Figure 1).

The microstructures of Piles 2 and 3 were essentially similar to that of Pile 1, consisting of fine pearlite and ferrite. The ferrite grain size of Piles 2 and 3 was slightly coarser (Figure 2).

MECHANICAL PROPERTIES

Transverse and longitudinal standard size Charpy V-notch samples were obtained. The samples were notched at right angles to the surface of the pile. Only longitudinal samples were taken for the tensile and bend tests. All test samples were obtained from the web of the piles. Results of the mechanical tests are shown below in Tables 2, 3, and 4. The Charpy results are shown graphically in Figure 3.

TABLE 2. - Tensile Test Results.

Pile	Sample Type	Strength, in psi		% Elongation	
		Ultimate	Yield	In 8 in.	In 2 in.
1	Full size	83,400	50,400	21	
2	"	74,500	50,900	20.2	
3	"	69,500	39,400	26.8	
1	Sub-size	85,800	50,200		36
1	"	85,600	50,200		30
2	"	72,300	45,200		34
3	"	81,300	46,200		34
Specification		71,000-85,000	43,000 min.	21 min.	

The bend test was satisfactory on both samples Nos. 2 and 3.

TABLE 3. - Results of Charpy V-notch Impact Tests on Steel Sheet Piling Samples 1, 2 and 3. (In foot-pounds)

Temp °F	Sample 1 Individual	Sample 1 Av'ge	Sample 2 Individual	Sample 2 Av'ge	Sample 3 Individual	Sample 3 Av'ge
	Longitudinal					
0	4, 4, 3	3.7	3, 2, 2	2.3	4, 3, 2	3
32	8, 7, 5	6.7	6, 11, 8	8.4	10, 8, 8	8.7
50	-	-	17, 16, 12	15.0	8, 10, 9	9
78	16, 14, 17	15.7	38, 15, 21	24.6	32, 24, 20	25.3
110	-	-	24, 46, 43	37.7	42, 50, 48	46.6
160	-	-	60, 70, 62	64	68, 68, 65	67
212	36, 37	36.5	62, 41, 67	56	63, 60, 63	62
	Transverse					
0	4, 4	4	3, 2, 2	2.3	3, 2, 2	2.3
32	6, 6	6	6, 4, 4	4.7	6, 4, 6	5.3
50	-	-	9, 8, 8	8.4	8, 6, 8	7.3
78	12, 12, 14	12.7	10, 12, 11	11.0	10, 12, 12	11.3
110	-	-	19, 20, 20	19.8	15, 17, 20	17.3
160	-	-	24, 24, 22	23.4	22, 21, 22	21.6
212	-	-	23, 22, 22	22.3	22, 24, 22	22.6

TABLE 4. - Summary of the Impact Test Results on Steel Sheet Piling Samples 1, 2 and 3.

Criterion	Longitudinal Pile 1	Longitudinal Pile 2	Longitudinal Pile 3	Transverse Pile 1	Transverse Pile 2	Transverse Pile 3
Transition temp. (°F), 15 ft-lb	74	55	55	92*	90	100
Transition temp. (°F), 50% fibrous fracture	100	110	110	Higher than 75	105	105
Energy absorbed, in ft-lb at 32°F	7	8	9	6	5	5

* Estimated.

DISCUSSION

The chemical analyses of the samples do not conform to the specification. The low manganese and silicon are unfavourable. The phosphorus content is down within the range of manufacturers' permissible variation on check analysis. The lower phosphorus is decidedly favourable. The aluminium and nitrogen levels are similar to those of Pile 1; hence, the strain-ageing characteristics of Piles 2 and 3 should be similar. As Pile 1 did not appear deficient in this respect, Piles 2 and 3 were not tested for this effect.

The yield strength and the ultimate tensile strength of the full size specimen of Pile 3 are both below specification. However, these properties of the sub-size specimen are comfortably within specification. This difference is not due to size, hence the sub-size specimen can be considered a satisfactory retest. While the elongation of the full size specimen of Pile 2 is not quite up to specification, the deficiency is considered insignificant.

As shown in Figure 3, the Charpy V-notch properties of Piles 2 and 3 are similar to those of Pile 1 for transverse samples and superior to Pile 1 for longitudinal samples, particularly at higher temperatures. In Table 5 below, the data on the Comeauville piling are compared with data for the Baie Comeau and the Burlington pilings. The Baie Comeau piling failed with a brittle fracture. Two of the Burlington piles failed with a brittle fracture in the presence of a prior fatigue crack; the other two failed by complete fatigue fracture. These piles are listed below as "Brittle Fracture" and "Fatigue Fracture", respectively. As data for longitudinal samples only are available for the Baie Comeau and Burlington piles, data from longitudinal samples only are shown for the Comeauville piling.

TABLE 5. - Comparative Impact Data on Piling from Three Sources.

	Baie Comeau Piling	Comeauville Piling			Burlington Piling	
		#1	#2	#3	Brittle Fracture	Fatigue Fracture
15 ft-lb transition temp, °F	94	74	55	55	54	26.5
Energy absorbed in ft-lb at 32°F	7	7	8	9	7	15
Energy absorbed in ft-lb at 78°F	11.5	16	24	25	24	49

While the data from Comeauville Piles 2 and 3 are marginally better than the data for Comeauville Pile 1, the comparative rating of this material has not been changed with respect to the other two sources, except to increase the very slight superiority over the Baie Comeau material.

Unfortunately, it is still impossible to state categorically that this material will fail or will not fail in service. It still appears that some degree of breakage is highly probable. The recommendations made in the previous report (PM3245), regarding precautions in flame cutting, welding, and handling are still applicable.

CONCLUSIONS

The data from Piles 2 and 3 confirm, for the most part, the findings on Pile 1, i. e.,

1. The analyses do not conform to specification.

2. Tensile and bend properties are satisfactory.

3. Comparison of the Charpy V-notch impact test data of this material with those of other samples of known service life does not justify outright condemnation of this material, but definitely does suggest a high probability of service failure.

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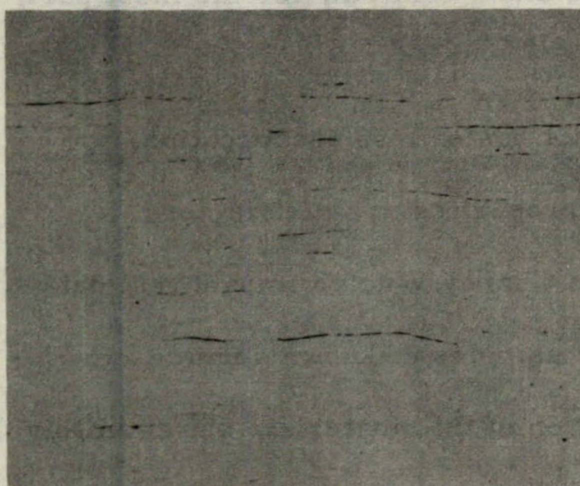
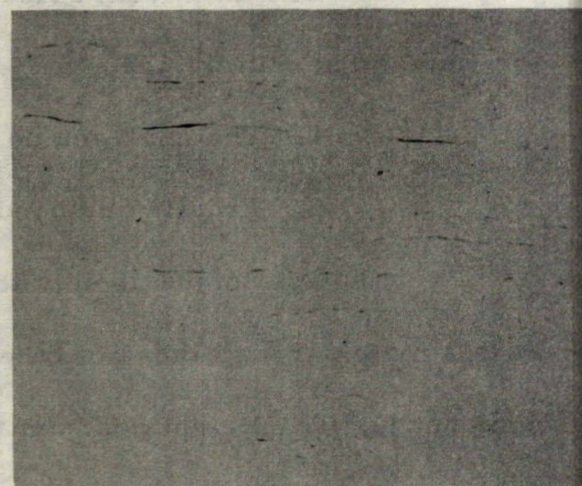
(Figures 1 to 3 follow,)
(on pages 8-10.)

Comeauville
Pile 1.



Comeauville
Pile 2.



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Comeauville
Pile 3.

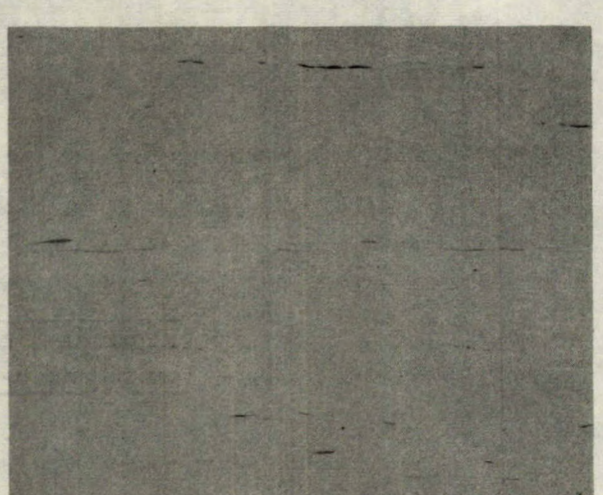

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Fig. 1. - Longitudinal sections at centre of piles.
(X100. Unetched.)

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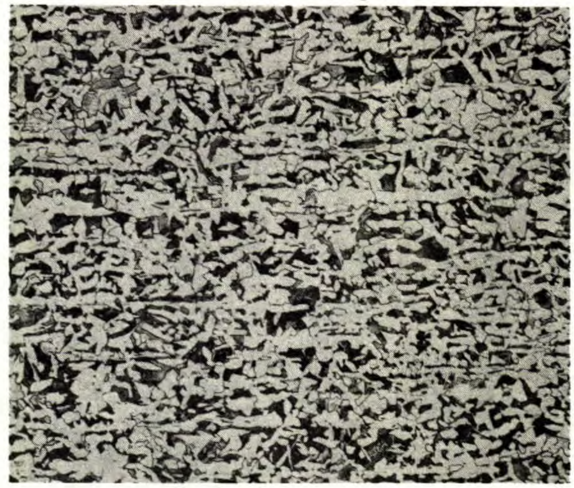
Centre | Outer edge

(a)



(b)

Comeauville Pile 1.

Centre | Outer edge

(c)



(d)

Comeauville Pile 2.

Centre | Outer edge

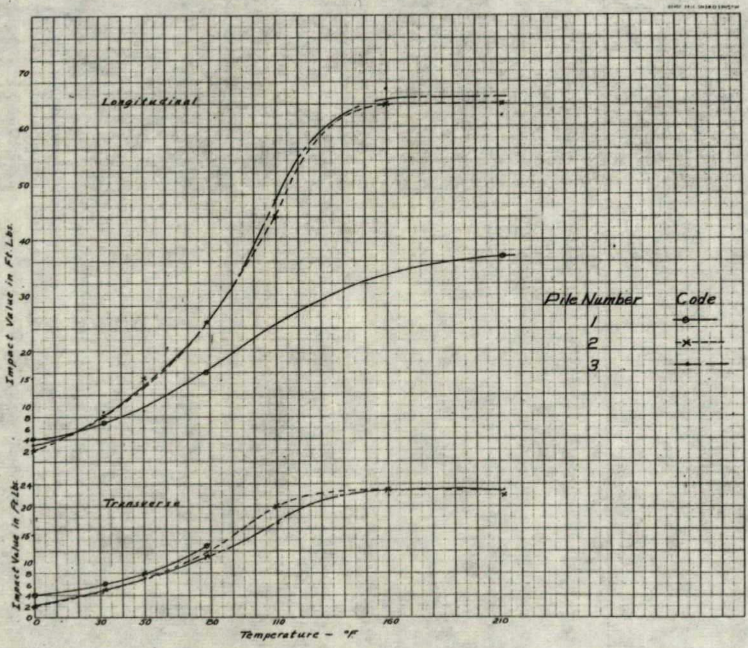
(e)



(f)

Comeauville Pile 3.

Fig. 2. - Photomicrographs of longitudinal sections.
(X100. Etched in 2% nital.)



<u>Fig. 3.</u> - Charpy V-notch impact test results.

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