CORROSION RESISTANCE OF STEEL SHEET PILES IN THE PORT OF TRONDHEIM - SURVEY REPORT

J. DECKER, Arbed Luxembourg, L

I. ABSTRACT

Project

Comparative measurements of the corrosion rate and the behaviour of corrosion protections at full scale on the "Transittkaia" in the port of Trondheim.

Scope of the Project

Determination of the effects of corrosion on steel sheet piling to provide basic calculation information for an evaluation of construction lifetime.

Description of the project

Collecting information about

- the evolution of the corrosion rates for different steel grades
- the increase of pratical lifetime by surface coating
- the possibility of directing the electrolytic process of the corrosion by welding of the sheet pile interlocks.

Presentation of the measurement procedure including preliminary results.

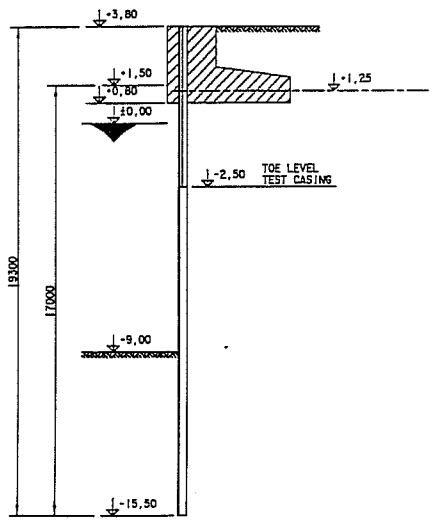
The whole measurement and recording campaign is projected for the time of 30 years.

II. INTRODUCTION

On the Transittkaia extension, realized in 1976 by a sheet pile construction, corrosion measurements are achieved since 1982.

The scope of the measurements is the study of the behaviour of the sheet structure against corrosion attack. The knowledge and information gathered in the test campaign shall be later the base for the structural design and a user consulting service

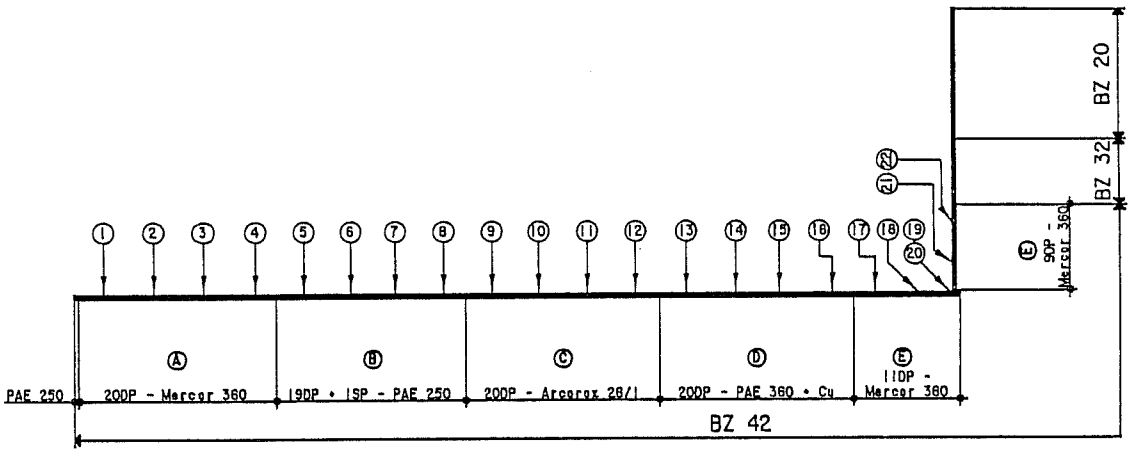
TYPICAL CROSS SECTION



On previously prepared steel sheet piles knowledge shall be gained

- on the corrosion intensity and distribution for various steel grades
- on a possible deviation of the electrolytical corrosion process from the sensitive points of the geometry of the pile section to the stronger interlock area
- on the increase of the service life of a steel sheet pile structure by various surface treatments.

1992, 10e Havencongres, Antw.



WATERSIDE

III. TEST ARRANGEMENT

The whole length of the quay wall consists of 5 areas (A-B-C-D-E) of a different steel grade each and built up of 20 double piles each.
Every area is subdivided in four sections:

- first sections with raw, absolutely untreated piles
- second section with untreated piles, but prepared to give a geometrical influence to the electrolytical corrosion attack
- third section with rough short life time coating
- fourth section with a more elaborated long lasting coating.

To take into account the possible influence of a geographical location, the two opposite areas A and E on the quay wall were identic.

Following is the description of the possible factors of influence considered in the research programme.

1. Steel grades

Measurements of the intensity of the corrosion attack were made on four different steel grades in the five areas of 20 double piles each.

In the alignment of the quay wall the areas have the following sequence:

area A MERCOR 360 similar to ASTM A 690, Mariner

B PAE 250 similar to Fe 360 B, StSp 37, E 240 SP

C ARCOROX 26/1 similar to Wt St 37-2

D PAE 360 + Cu similar to St 52-3 (+ Cu)

E MERCOR 360 identical to area A but continuing out of the alignment of the main wall into the wing wall.

2. Directing the electrolytical corrosion process

Arrangements were made to check the possibility for deviating the electrochemical component of the corrosion attack from the most sensitive parts of the sheet pile section to heavier and more resistant parts.
The interlocks of some double piles were welded together in the aeration zone, alternatively on the landside and the waterside.

3. Short time coatings

Low cost protective coatings with an assumed life time (increase of the service time of the structure) of about 5 years were applied to the waterside of the sheet piles.

Area A 1 layer coaltar - 40 my

B 1 layer Ferbit (bitume base) - 40 my

C 1 layer Bitumastic (bitume) - 150 my

D 1 layer tar emulsion - 150 my

E identical to A

4. Long time coatings

Sophisticated coating systems with an expected life time (increase of the service time of the structure) of about 15 years have been applied to the waterside of the sheet piles.

Area A sandblasting SA 2,5
1 layer zinctich primer - 50 my
2 layers coaltar epoxy - 100 my
Total coating thickness 250 my

B sandblasting SA 2,5
3 layers of coaltar for epoxy - 130/135 my
Total coating thickness 400 my

C sandblasting SA 2,5
1 layer coal for epoxy - 100 my
1 layer Bitumastic - 300 my
Total coating thickness 400 my

E sandblasting SA 2,5
1 layer zincrich primer - 50 my
1 layer Nervoplan (bitume base) - 350 my
Total coating thickness 400 my

The last coating has not been realized (Nervoplan).
It had been foreseen to make the application on port site, but the general conditions at that time make it impossible.

For the same reasons of organisation difficulties a cathodic protection with sacrified anods that had been foreseen was abandoned.

IV. REGISTRATION METHOD OF THE CORROSION RATES

1. General

The measuring of the reduction of the wall thickness of the sheet piles by corrosion was achieved by ultrasonic device from the backside of the pile.

To allow multiple measurements, in every section some double piles had been provided with a test casing on the landside. These casings had been welded on the piles in a work shop. Into these channels a record, equipped with two ultrasonic measuring heads, is introduced and the wall thickness is registered.

To guarantee a perfect contact between sheet pile and measuring head the inside of the channels has been prepared metallic white and then filled with paraffine. The neutral oil provides a good contact for the measurements and at the same time avoids corrosion from the inside. The location of the casings and the design of the ultrasonic recorder give the possibility to take measurements on web and flange of the pile at the same time and cover the whole length of a pile just by up and down movement.

2. Special aspects

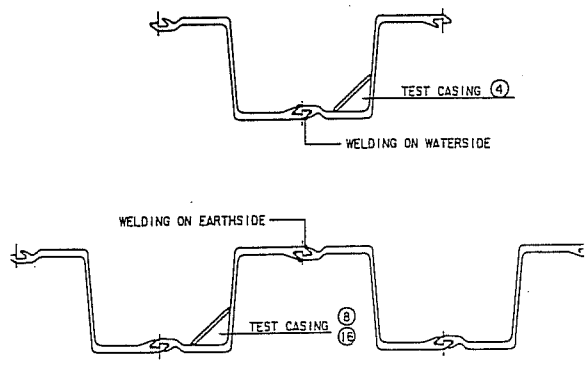
A gauging of the recorder was achieved on specially fabricated piles, prepared under laboratorium conditions, giving the system an exactitude and reliability of +/- 0,1 mm.

To put the corrosion results into relation with their environmental conditions on analysis of the chemical composition of the water in the port has been achieved an a sample taken on the 20.06.91.

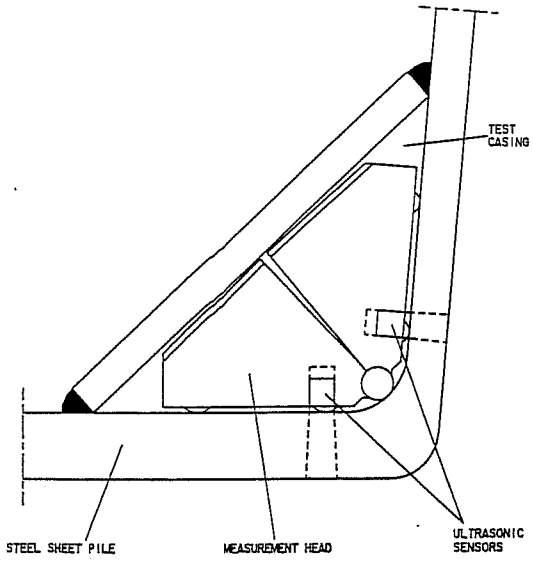
ANALYSIS:

COND. (u$/cm)	9720
pH	6,8
TA (OF)	<0,01
TAC (OF)	5,90
Cl (mg/l)	3151
SO4 (mg/l)	531
NO3 (mg/l)	0,20
Fe (mg/l)	<0,10
Zn (mg/l)	0,040
Cu (mg/l)	<0,10
Mg (mg/l)	213
Na (mg/l)	1670
K (mg/l)	77

DETAILS OF TEST CASING ARRANGEMENTS



REPRESENTATION OF THE MEASURING SYSTEM



V. TEST EVALUATION

It must be emphasized that this report can only show a summary of the total corrosion on the various steel sheet piles over a certain period to give a first impression about the effectiveness of the different approaches:

- the different unprotected steel grades do not show considerable variations in there maximum corrosion rates. The resulting values for PAE 250, PAE 360 + Cu and MERCOR 360 are in the same range. A real surprise are the good results of ARCOROX 26/1 especially because used out of its real field of application.

- the welding achieved on the sheet pile interlocks did not result in any notable influence on the electrolytical corrosion process.

- corrosion rate ratio between flange and web does no show a significant difference, but nevertheless a slight tendency to a greater corrosion on the flange must be noted.

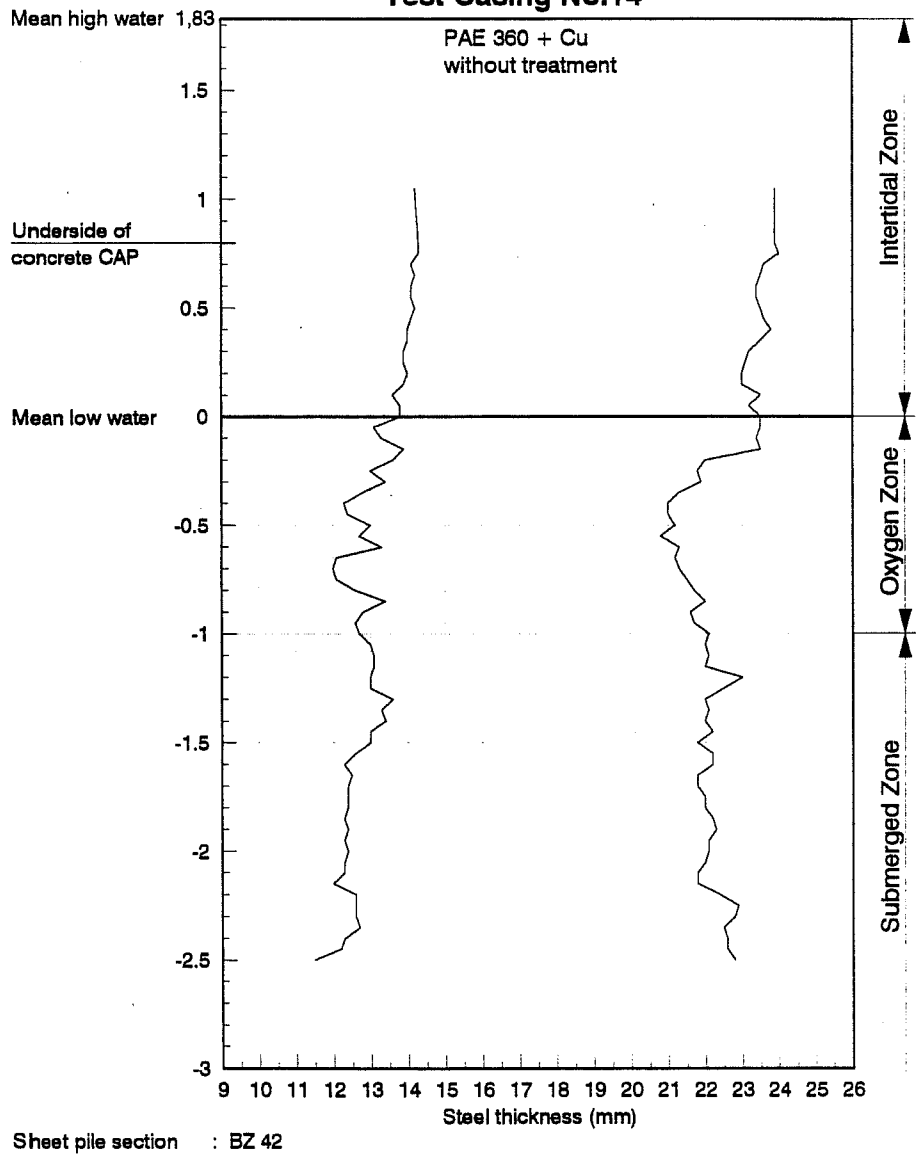
- an evaluation of the total corrosion and the average corrosion per year between untreated sheet piles and sheet piles with a short life treatment shows a retarding effect of more than 4 years, being a good confirmation for the initially assumed 5 years lifetime for such a treatment. After this delay the reaction of the steel is as for non coated structures. The different surface treatments applied show nearly equivalent performances.

- the recorded values prove the justification for the more sophisticated systems; the results depending on the invests i.e. nature of primer and top layers, number and thickness of layers.

CONCLUSION:

Since the whole test campaign is projected for 30 years, meaning the present values are half-time results, no definite conclusion should be made and no comparison with other corrosion researches on steel sheet piles seems to be possible.

Test Casing No.14



Sheet pile section : BZ 42
Theoretical thickness : Flange = 24 mm
Web = 14 mm

Record : June 1991

Relation Flange / Web (Total corrosion over 15 years / 1976 ÷ 1991)

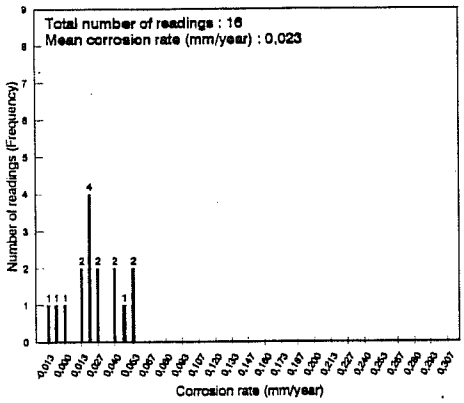
Corrosion zones	Total corrosion zone (mm)	Intertidal zone (mm)	Oxygen zone (mm)	Submerged zone (mm)
Flange	1,40	0,35	1,94	1,58
Web	1,26	0,27	1,39	1,68
Ratio $\frac{\text{Flange}}{\text{Web}}$	1,111	1,296	1,396	0,940

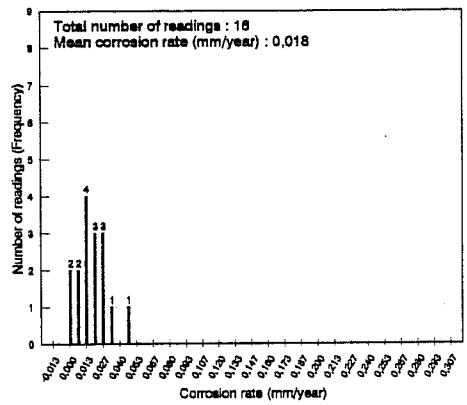
Test casing No.14
Corrosion rate frequency distribution

Flange

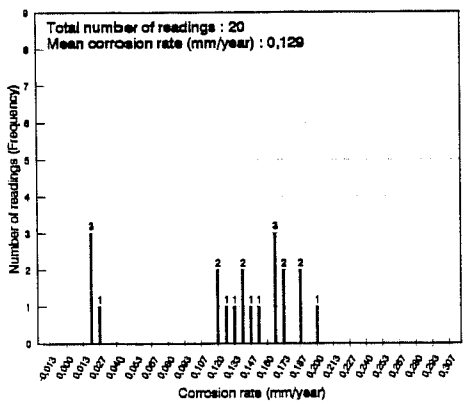
Web

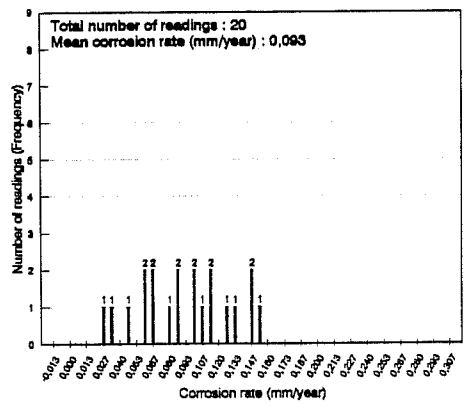
Intertidal zone



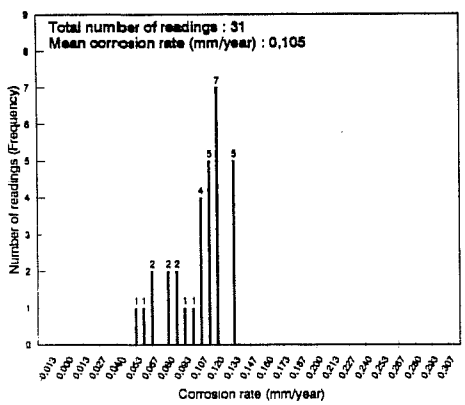


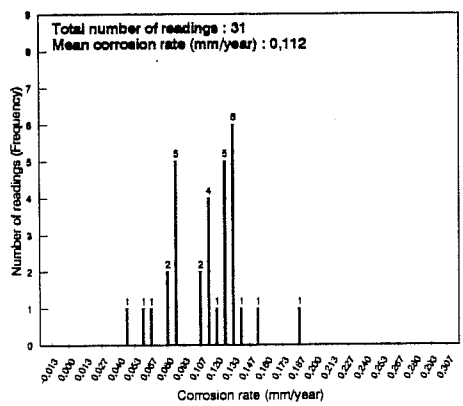
Oxygen zone



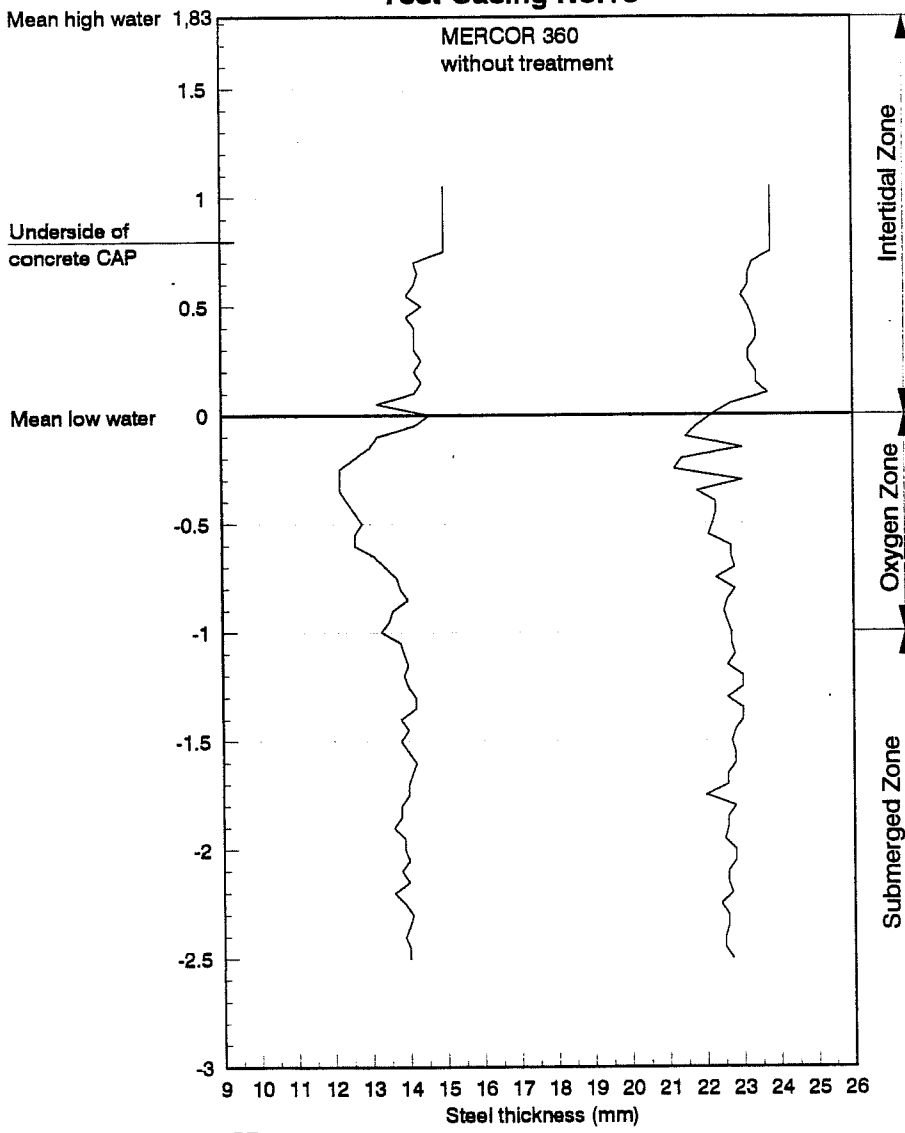


Submerged zone





Test Casing No.18



Sheet pile section : BZ 42
Theoretical thickness : Flange = 24 mm
Web = 14 mm

Record : June 1991

Relation Flange / Web (Total corrosion over 15 years / 1976 ÷ 1991)

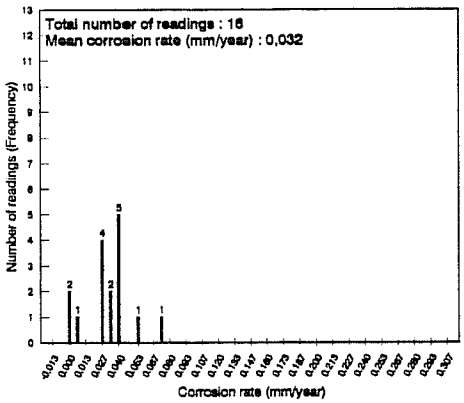
Corrosion zones	Total corrosion zone (mm)	Intertidal zone (mm)	Oxygen zone (mm)	Submerged zone (mm)
Flange	1,08	0,48	1,51	1,12
Web	1,24	0,74	1,89	1,08
Ratio $\frac{\text{Flange}}{\text{Web}}$	0,871	0,649	0,799	1,039

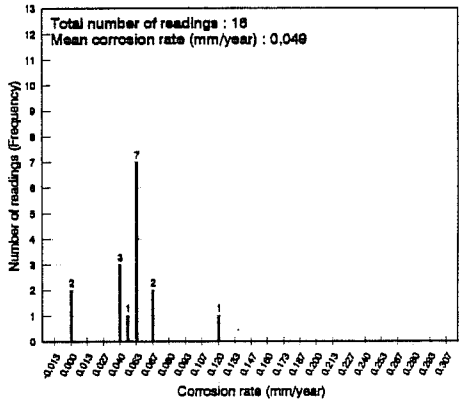
Test casing No.18
Corrosion rate frequency distribution

Flange

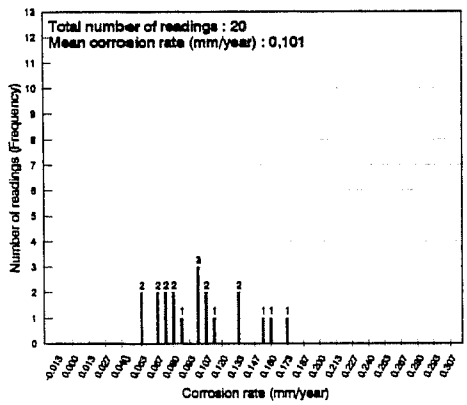
Web

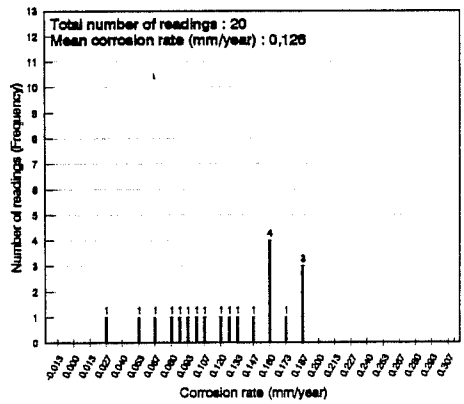
Intertidal zone



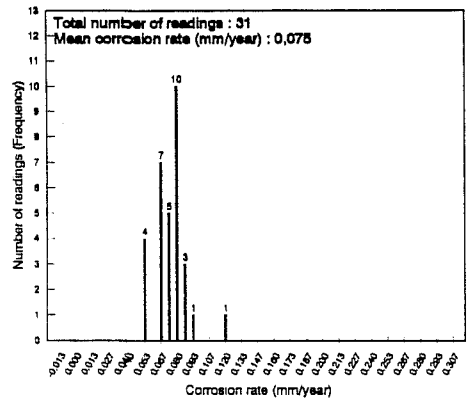


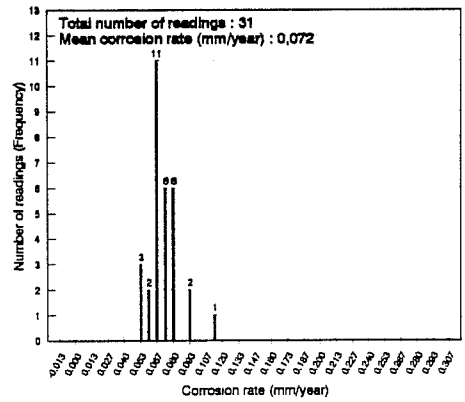
Oxygen zone



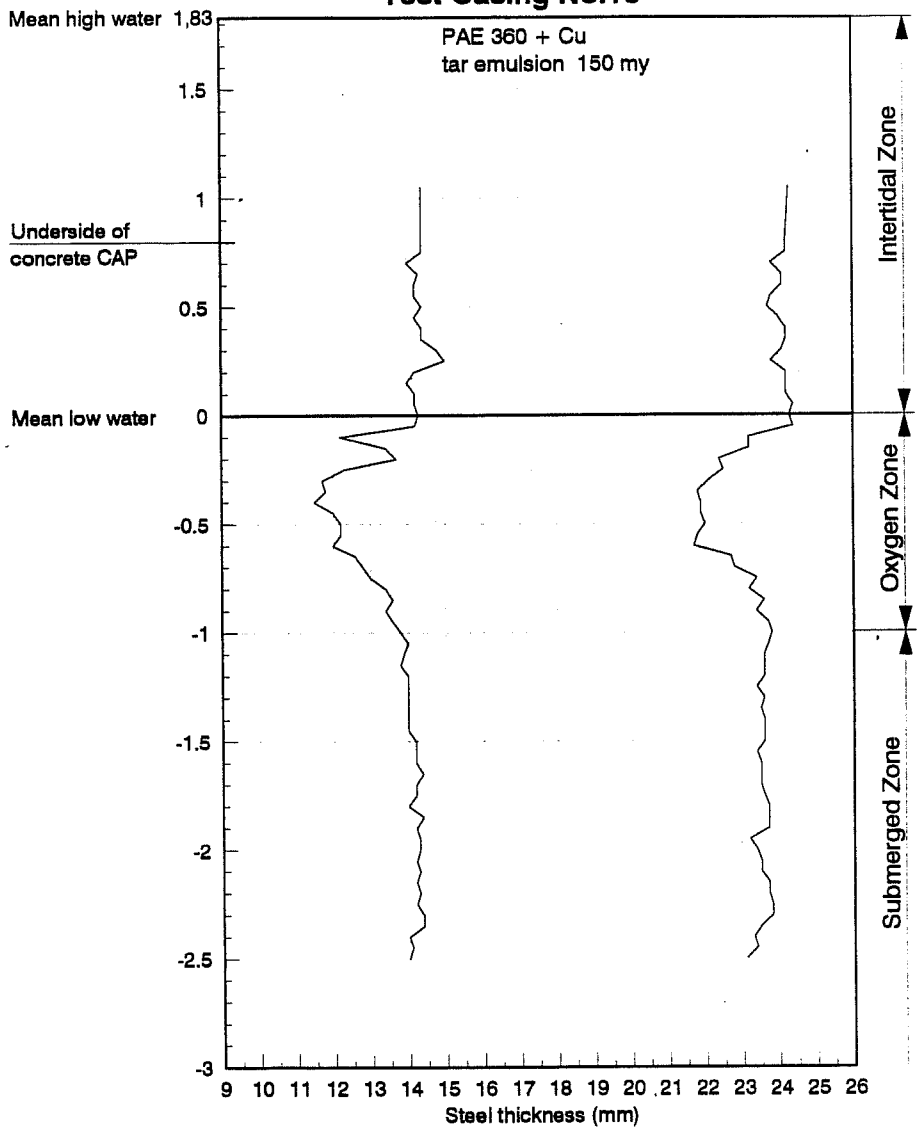


Submerged zone





Test Casing No.15



Sheet pile section : BZ 42
Theoretical thickness : Flange = 24 mm
Web = 14 mm

Record : June 1991

Relation Flange / Web (Total corrosion over 15 years / 1976 ÷ 1991)

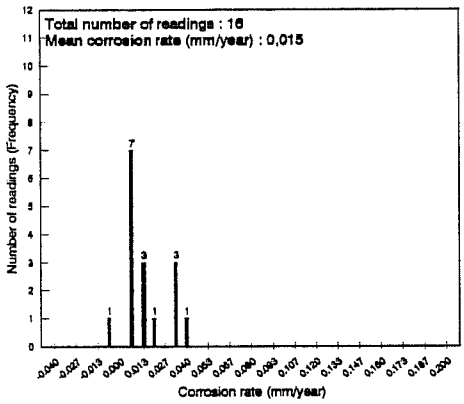
Corrosion zones	Total corrosion zone (mm)	Intertidal zone (mm)	Oxygen zone (mm)	Submerged zone (mm)
Flange	0,85	0,23	1,50	0,75
Web	0,62	0,07	1,61	0,26
Ratio $\frac{\text{Flange}}{\text{Web}}$	1,371	3,286	0,932	2,885

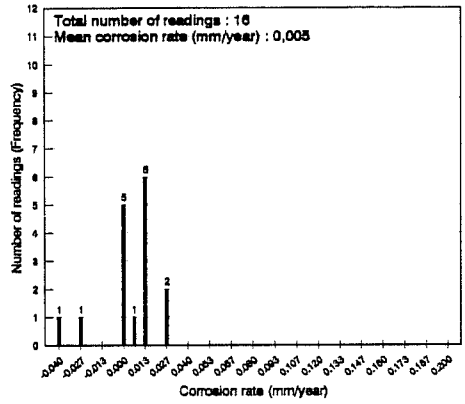
Test casing No.15
Corrosion rate frequency distribution

Flange

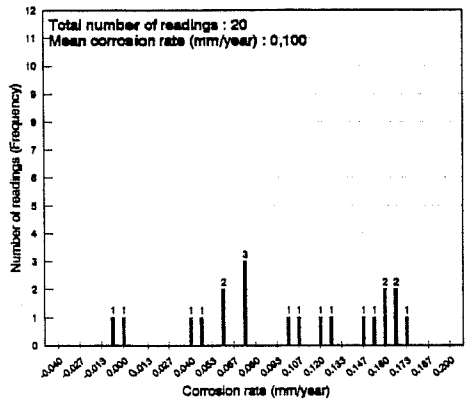
Web

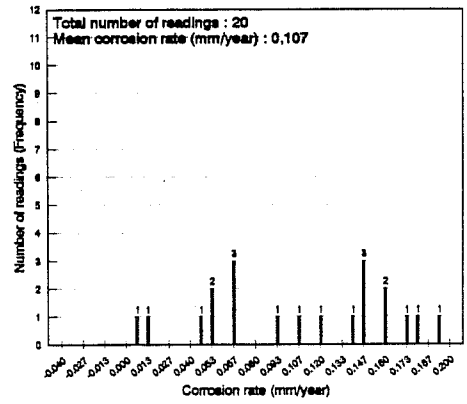
Intertidal zone



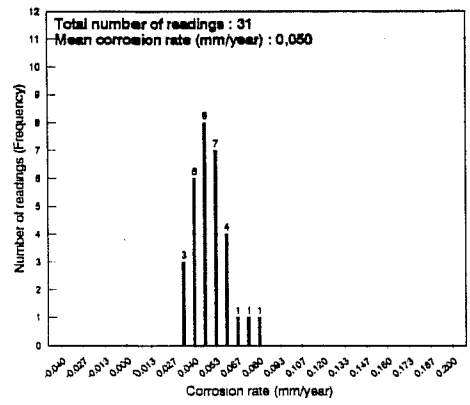


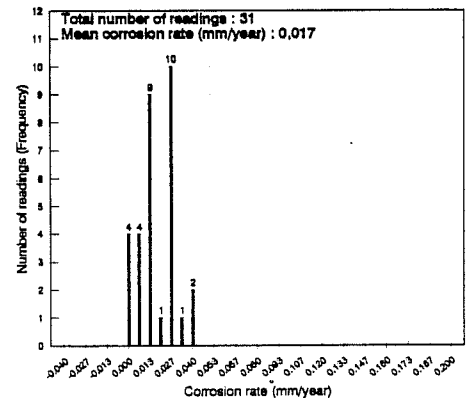
Oxygen zone



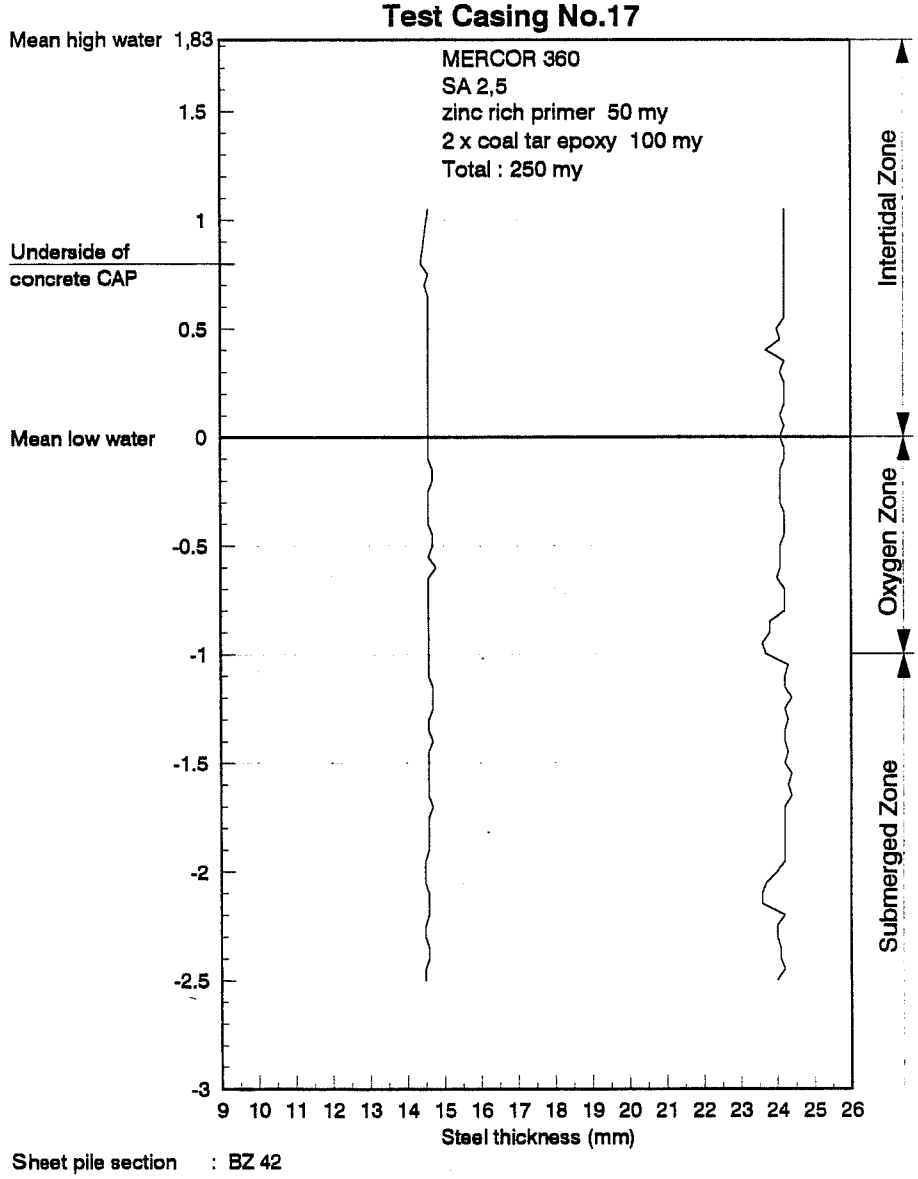


Submerged zone





Test Casing No.17



Sheet pile section : BZ 42
Theoretical thickness : Flange = 24 mm
Web = 14 mm

Record : June 1991

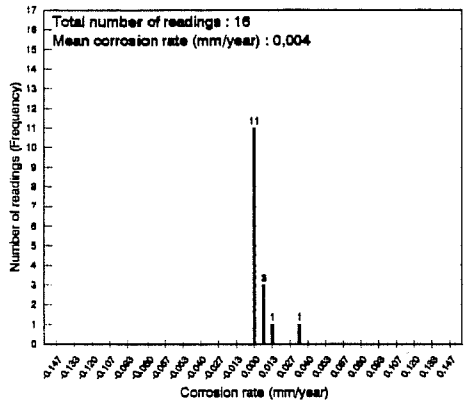
Relation Flange / Web (Total corrosion over 15 years / 1976 ÷ 1991)

Corrosion zones	Total corrosion zone (mm)	Intertidal zone (mm)	Oxygen zone (mm)	Submerged zone (mm)
Flange	0,08	0,06	0,12	0,07
Web	0,00	0,02	-0,03	0,01
Ratio $\frac{\text{Flange}}{\text{Web}}$	/	/	/	/

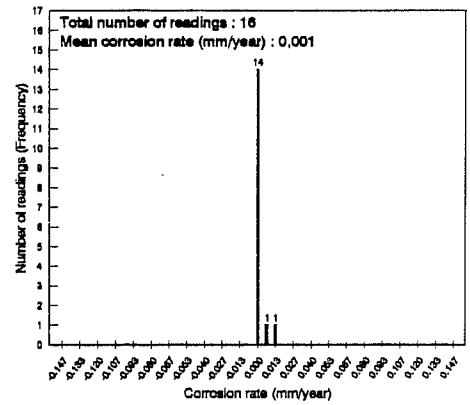
Test casing No.17
Corrosion rate frequency distribution

Intertidal zone

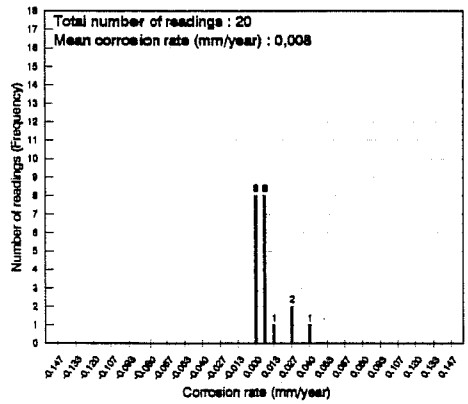
Flange

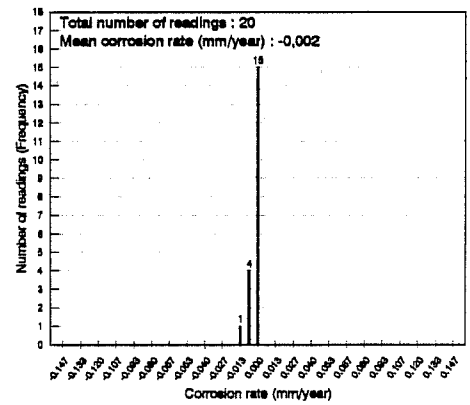


Web

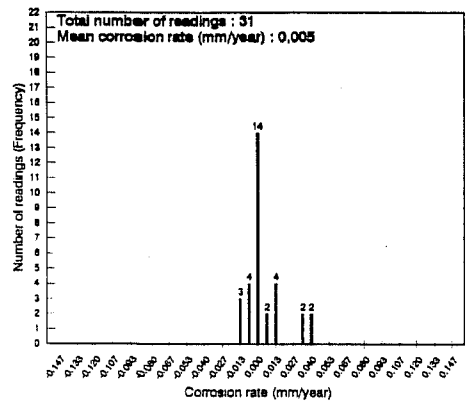


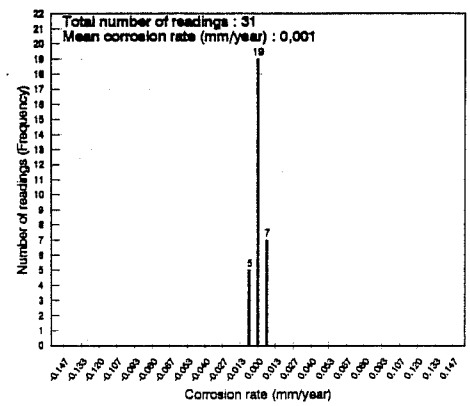
Oxygen zone





Submerged zone





CORROSION RATE (mm/year)

Flange

Steel Grade	Without treatment				Without treatment + welding				Short life treatment				Long life treatment			
	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone
PAE 250	0,157	0,041	0,176	0,205	0,096	0,046	0,147	0,089	0,065	0,031	0,101	0,060	0,015	0,011	0,017	/
PAE 360 + Cu	0,093	0,023	0,129	0,105	0,123	0,017	0,159	0,153	0,057	0,015	0,100	0,050	0,059	0,017	0,058	0,081
MERCOR 360	0,072 0,102	0,032 0,040	0,101 0,148	0,075 0,105	0,080 0,078	0,033 0,050	0,112 0,120	0,084 0,065	0,059 0,054 0,064	0,031 0,016 0,041	0,099 0,085 0,100	0,047 0,052 0,053	0,005 /	0,004 /	0,008 /	0,005 /
AR COROX 26/1	0,080 0,049	0,033 0,013	0,101 0,081	0,090 0,051					0,049	0,027	0,069	0,045	−0,018	0,014	0,013	/

Web

Steel Grade	Without treatment				Without treatment + welding				Short life treatment				Long life treatment			
	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone
PAE 250	0,139	0,024	0,179	0,171	0,109	0,033	0,141	0,127	0,041	0,014	0,056	0,047	−0,012	0,009	0,001	/
PAE 360 + Cu	0,084	0,018	0,093	0,112	0,115	0,023	0,143	0,145	0,041	0,005	0,107	0,017	0,060	0,012	0,049	0,091
MERCOR 360	0,083 0,084	0,049 0,041	0,126 0,127	0,072 0,079	0,079 0,060	0,022 0,029	0,098 0,097	0,096 0,053	0,049 0,062 0,039	0,025 0,037 0,036	0,069 0,089 0,065	0,048 0,057 0,023	0,000 0,000	−0,005 0,001	−0,003 −0,002	0,004 0,001
AR COROX 26/1	0,058 0,061	0,022 0,038	0,089 0,087	0,057 0,055					0,027	0,017	0,035	0,028	−0,012	−0,009	−0,001	/

RATIO $\frac{\text{Flange}}{\text{Web}}$

Steel Grade	Without treatment				Without treatment + welding				Short life treatment				Long life treatment			
	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone	Total corr. zone	Intertidal zone	Oxygen zone	Submerged zone
PAE 250	1,135	1,722	0,978	1,195	0,883	1,380	1,047	0,696	1,581	2,190	1,798	1,286	/	/	/	/
PAE 360 + Cu	1,111	1,296	1,396	0,940	1,064	0,765	1,112	1,055	1,371	3,286	0,932	2,885	0,978	1,444	1,176	0,883
MERCOR 360	0,871	0,649	0,799	1,039	1,017	1,485	1,143	0,875	1,205	1,243	1,433	0,972	/	/	/	/
	1,214	0,984	1,168	1,319	1,300	1,705	1,241	1,241	0,871	0,462	0,982	0,918	/	/	/	/
									1,655	1,148	1,546	2,257				
AR'COROX 26/1	1,379	1,515	1,143	1,588					1,780	1,577	1,962	1,619	/	/	/	/
	0,802	0,351	0,862	0,916												