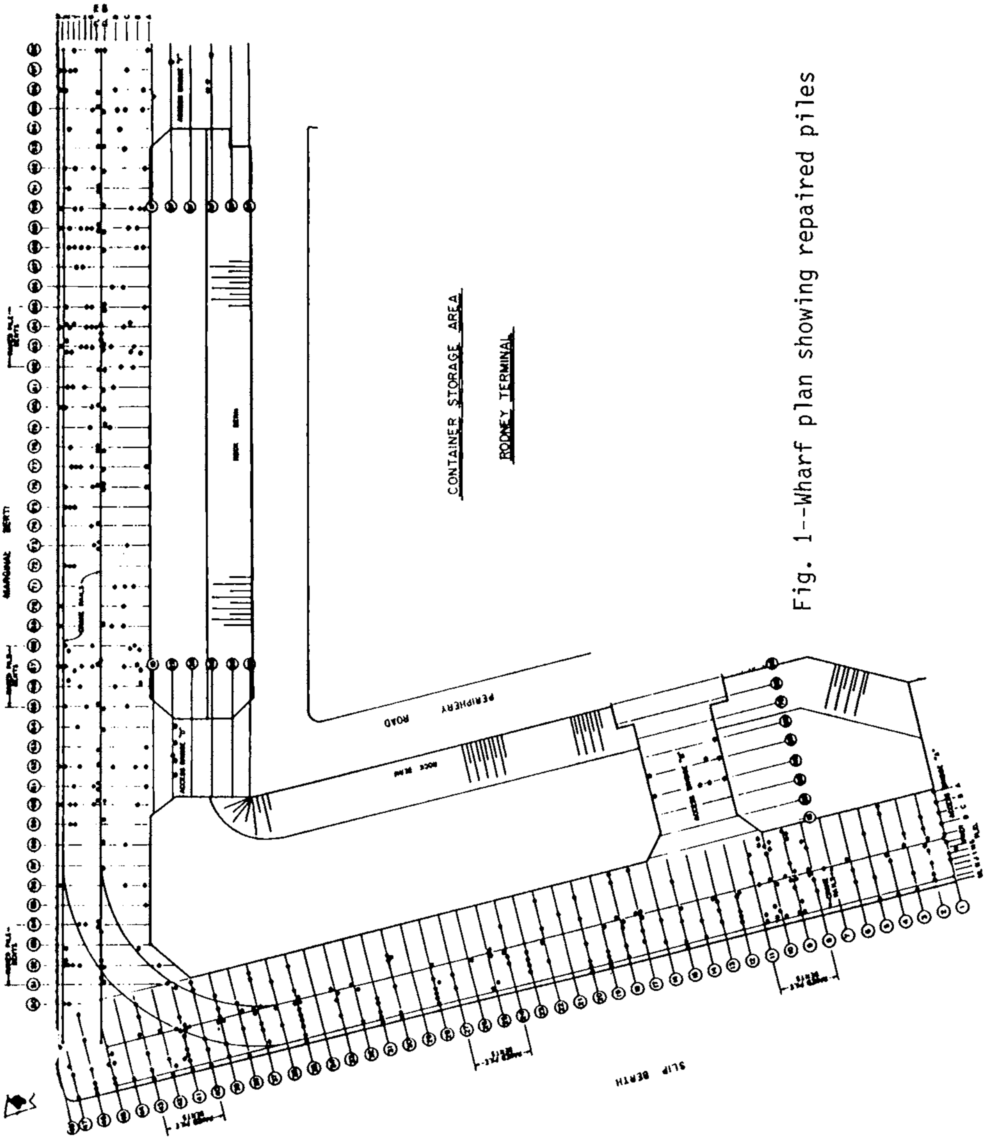

Fig. 1--Wharf plan showing repaired piles

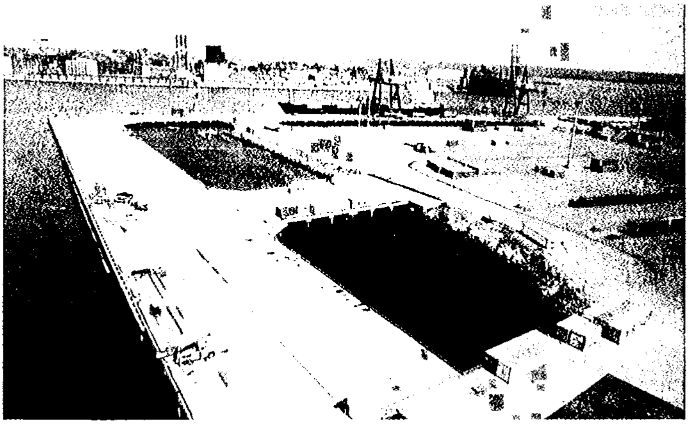

Fig. 2--Rodney Terminal — birdseye view

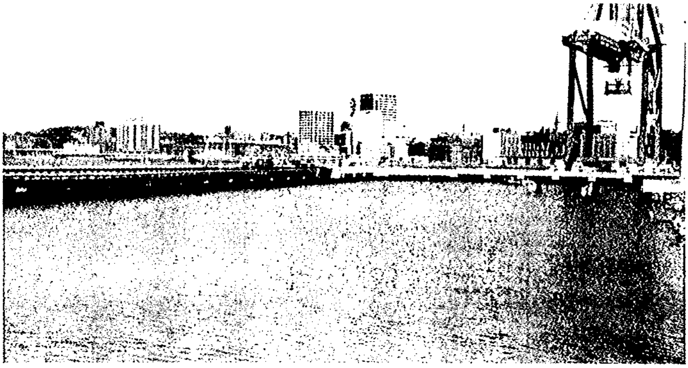

Fig. 3--Rodney Terminal — wharf at high tide

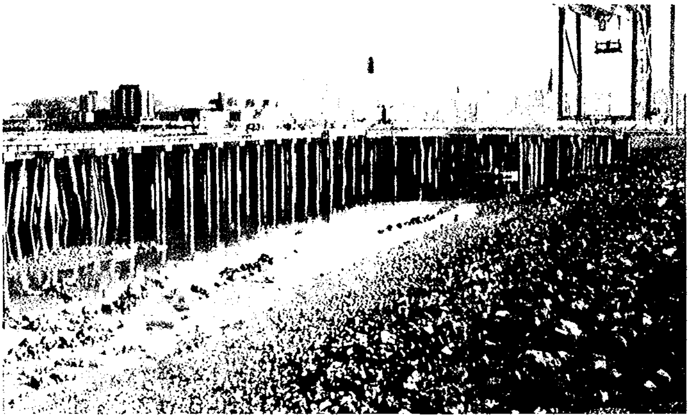

Fig. 4--Rodney Terminal — wharf at low water

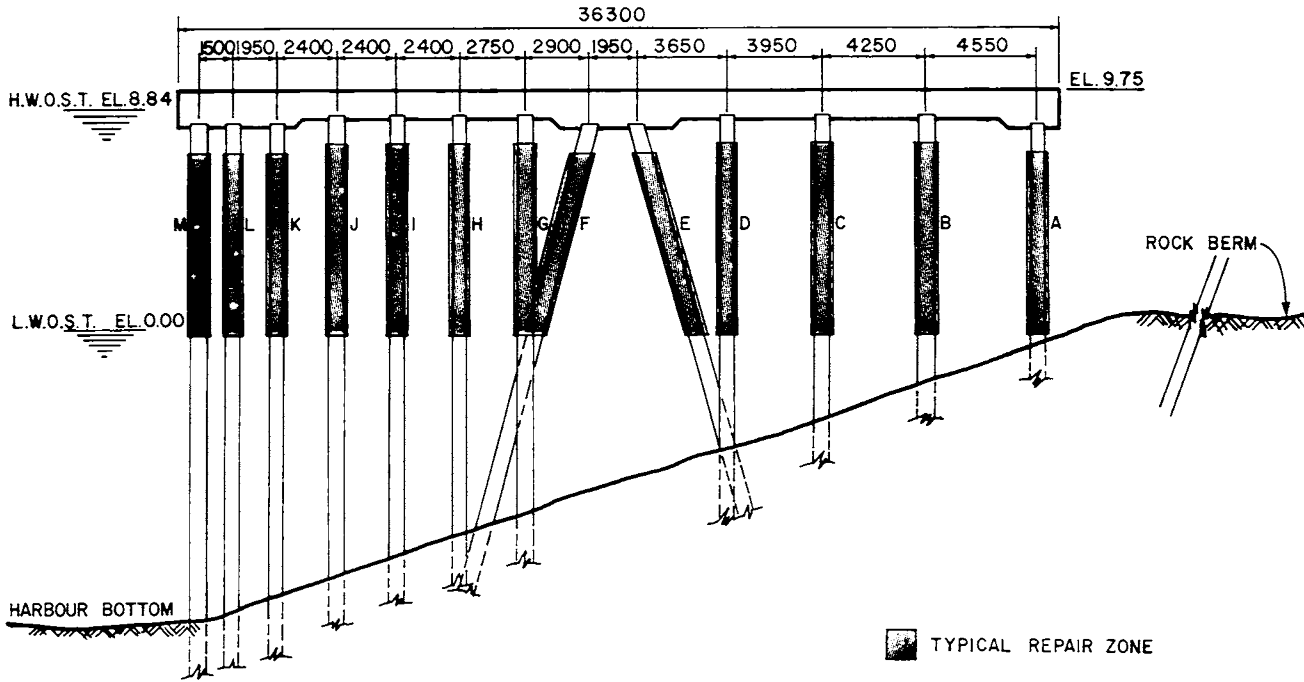

Fig. 5--Typical pile bent showing repair zone

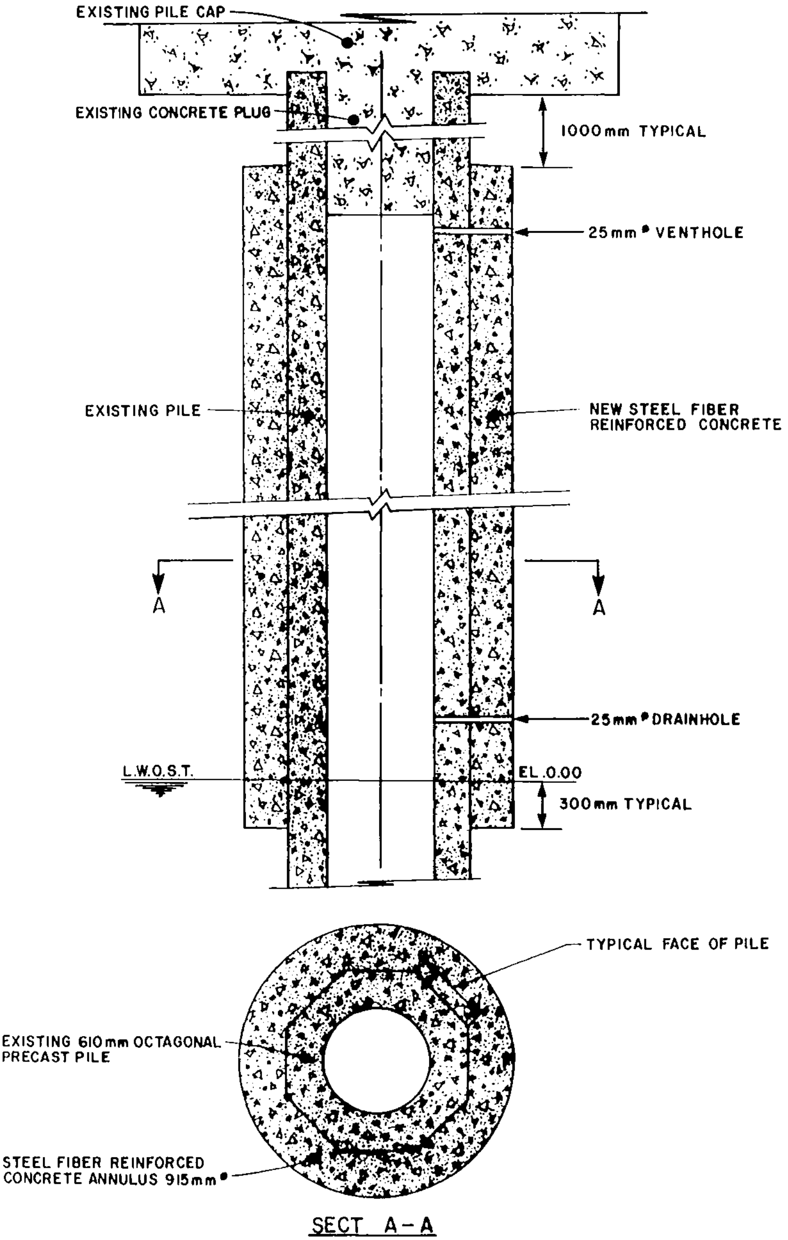

Fig. 6--Pile section showing SFRC jacket

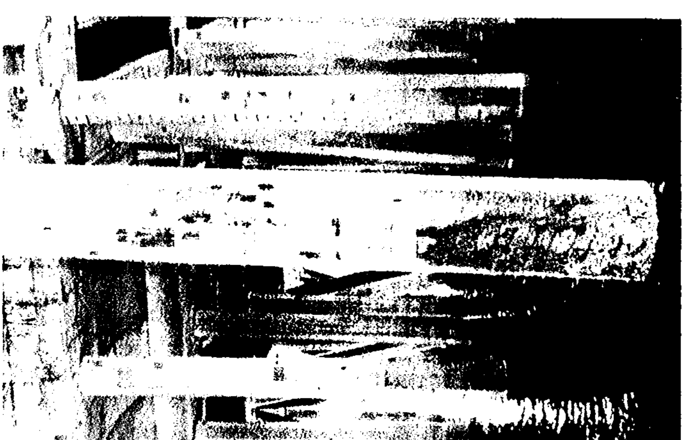

Fig. 7--Distressed pile before repair

Fig. 8--Pile after repair — collated fibers

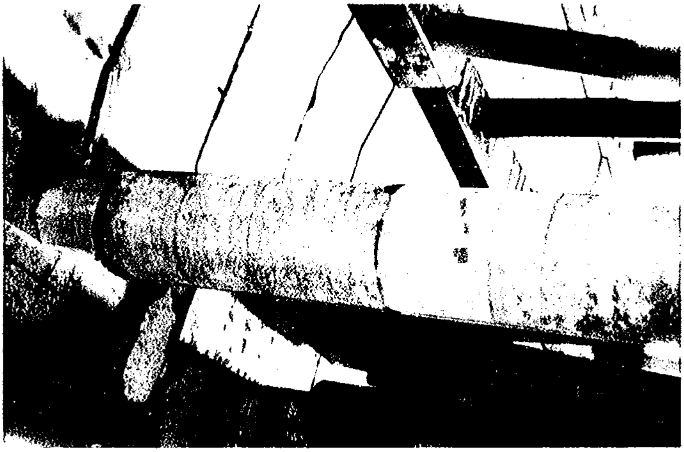

Fig. 9--Pile after repair — uncollated fibers

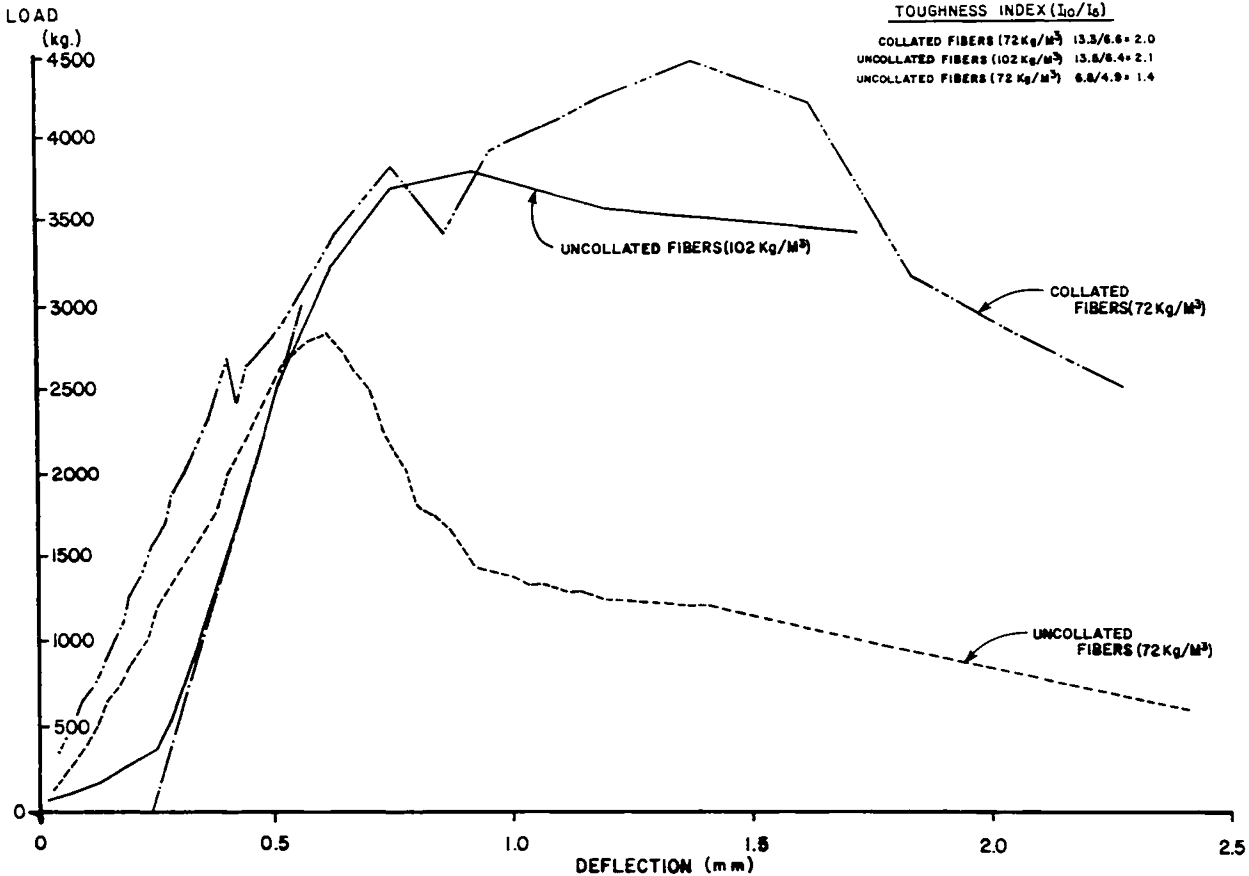
LOAD (kg.)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
TOUGHNESS INDEX (I_{10}/I_5)
COLLATED FIBERS (72 Kg/M³) 13.3/6.6 = 2.0
UNCOLLATED FIBERS (102 Kg/M³) 13.6/6.4 = 2.1
UNCOLLATED FIBERS (72 Kg/M³) 6.8/4.9 = 1.4
UNCOLLATED FIBERS(102 Kg/M³)
COLLATED FIBERS(72 Kg/M³)
UNCOLLATED FIBERS (72 Kg/M³)
0
0.5
1.0
1.5
2.0
2.5
DEFLECTION (mm)

Fig. 11--SFRC cracks

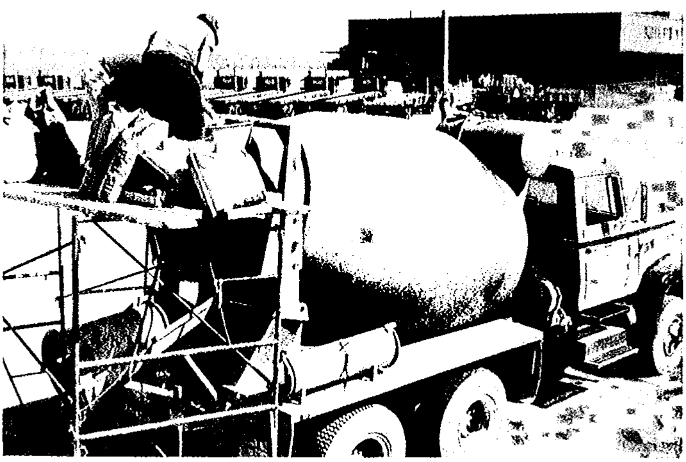

Fig. 12--Fibers added to truck mixes

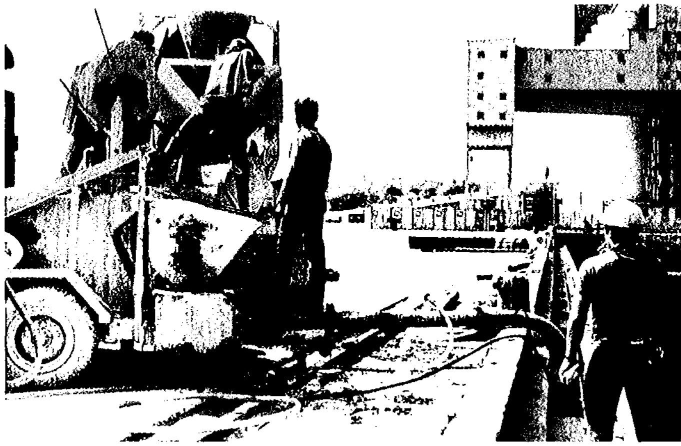

Fig. 13--Pumping SFRC

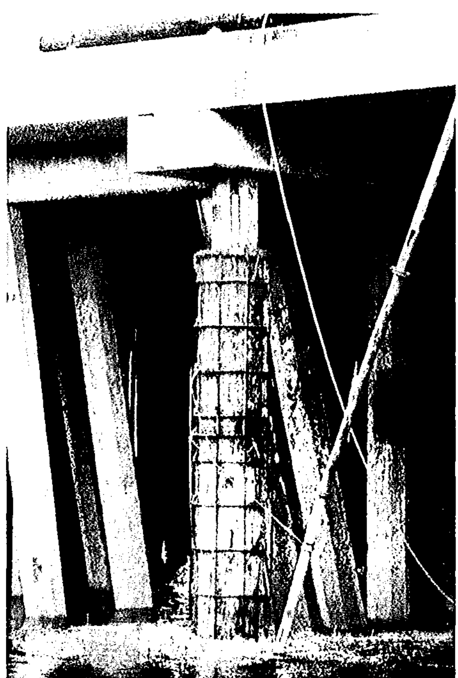

Fig. 14--SFRC overflowing form

SP 109-12

An Experimental Study on Deterioration and Repairing of a Marine Concrete Structure

by Y. Takagishi, H. Ichikawa,
H. Tabuchi, and A. Moriwake

Synopsis: Load carrying capacity and fatigue strength before and after repairing were investigated for a coastal structure in Tokyo Bay, which was subjected to a serious damage by chloride during 15 years. Static and cyclic load tests together with investigation on effectiveness of repair were carried out on specimens taken from the site. It was found that the bearing and yielding capacities of deteriorated slab are 90% and 80%, respectively of those of sound structure. These losses were mainly caused by 10% loss of reinforcement corrosion. The specimens repaired by material with high tensile strength suggested brittle failure in static load test. It was also found that fatigue failure of deteriorated reinforcements was accelerated by pitting corrosion.

Keywords: bridge decks; concrete slabs; corrosion; deterioration; epoxy resins; evaluation; fatigue strength; marine atmospheres; polymer-cement concrete; repairs

Y. Takagishi has studied marine concrete structures for a number of years. Now an assistant manager of the facility construction and maintenance department, Sodegaura Works, Tokyo Gas Corporation. H. Ichikawa has also studied marine concrete together with Y. Tkagishi and now a chief of the facility construction and maintenance department, Negishi Works, Tokyo Gas Corporation. H. Tabuchi has developed a special type of concrete for marine environments. Now a chief of the committee for concrete in Toa Corporation. A. Moriwake has been closely associated with concrete in marine environments for a number of years. Now a chief of Material laboratory, Technical Research Institute, Toa Corporation.

INTRODUCTION

Before repairing deteriorated concrete structure, it is important to evaluate the remaining load carrying capacity and/or fatigue strength of the structure. A series of static and cyclic load tests were carried out on an actual structure, exposed to serious chloride attack. The defective concrete slabs were repaired and the effectiveness of filling material was investigated. The model test was also performed on beam specimens to evaluate the relationship between the effectiveness of repairing and mechanical properties of filling material. The study consisted of 1)conditions of deteriorated structure in Tokyo Bay, 2)evaluation of static and cyclic load tests on deteriorated slab and 3)study on state of deteriorated slab and efficiency of repairing.

THE DETERIORATED STRUCTURE

The structure is an access bridge, 400m long constructed on Tokyo Bay 15 years ago. Concrete slab on the surface of this bridge was 16cm thick and was seriously damaged by chloride. It was double reinforced one with 3cm cover, overlaid by asphalt pavement. The slab consisted of air-entrained concrete formed of W/C=0.5 (water and cement content, 1.5kN/m^3 and 3.0kN/m^3 respectively) had a compressive cylinder strength of 27MPa. The lower level of the slab was +6.55m, and the low water and high water levels in this area are 0.0m and +2.0m, respectively. Significant wave heights adopted in design were +0.5m on an average and with +3.0m maximum. The average temperature and humidity in this area are 26 C and 75% in summer and 5 C and 55% in winter respectively (1).

Deterioration study of these slabs was carried out in 1984 and 1985. Damage was found at the bottom of slabs. Scabbing and spalling, which could be observed a little in the first investigation, was clearly seen in the second investigation which demonstrated that deterioration had progressed rapidly in one year. Corrosion damage of lower reinforcement measured in the second investigation was serious. Corroded conditions of reinforcing bars could be classified into the two patterns as presented in Fig.1. Sectional area of reinforcement after corrosion was calculated by eq. (1).

Pattern A : $A = 1/4 \cdot \pi \cdot b^2 - (b/2)^2 \cdot (2 \cdot \theta - \sin\theta)$ (1-1)

Pattern B : $A = \pi/4 \cdot a \cdot b$ (1-2)

where A=Area of reinforcing bar (m^2)
a,b=Measurements of reinforcement as shown in Fig.1 (m)
$\theta = \sin^{-1}((b/2)/(a-b/2))$

Chloride content in concrete was measured by potentiometric titration using silver nitrate and is plotted in Fig.2. Chloride content near the reinforcement exceeded the allowable value, 0.025% by the weight of concrete, according to the standard of The Japan Society of Civil Engineers (2). There was, however, no significant corrosion on the upper reinforcement. Carbonation was observed up to a depth of only 2.4mm from the concrete surface.

TESTS CONDUCTED

For Deteriorated Slabs

The deteriorated slabs, 4.1m wide and 12m long, were taken out from the structure. After the deterioration was investigated, 6 test specimens, 1.0m wide and 3.0m long, were cut out and three specimens each were used for static and cyclic load tests. In order to compare the strength of damaged and sound specimens, one specimen each was freshly cast. The extent of deterioration of each specimen was different and percentage of remaining sectional area of