Research on RC structure housing an old communication system for northern territory*1

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Abstract

Before World War II, an ocean floor cable was laid between Nemuro city and Kunashiri Island in Japanese northern territory. Then a reinforced concrete structure was built as a communication system in Nemuro City. The structure is located near the beach line of about 12 m. The external deterioration is very severe in the cold sea environment due to the penetration of salt at the splash zone and the many cycles of freezing and thawing over many years.

The purpose of this research was to investigate the deterioration of the concrete and the corrosion level of the reinforcing steel in order to predict the service life of the concrete structure. Also, a repair method is studied to preserve this structure.

1. Introduction

Before the Second World War, a cable, as shown in Photo. 1, was laid on the ocean floor between Nemuro city and Kunashiri Island of the Japanese northern territory which has been occupied by Russia since 1945. The location of the structure and the cable is shown in Fig. 1. Subsequently, a reinforced concrete structure was built as a communication system in Nemuro city as shown in Photo. 2. The structure is located about 12 m from the beach line as shown in Photo. 3. The external condition of deterioration is very severe in due to the cold sea environment such as penetration of salt at splash zone and due to the many cycles of freezing and thawing throughout the long year.

The basic purpose of this research is to investigate and study the deterioration level of the concrete and the corrosion level of the reinforcing steel in order to predict the service remaining life of the concrete structure. Furthermore, an appropriate repair method to preserve this structure is being studied.

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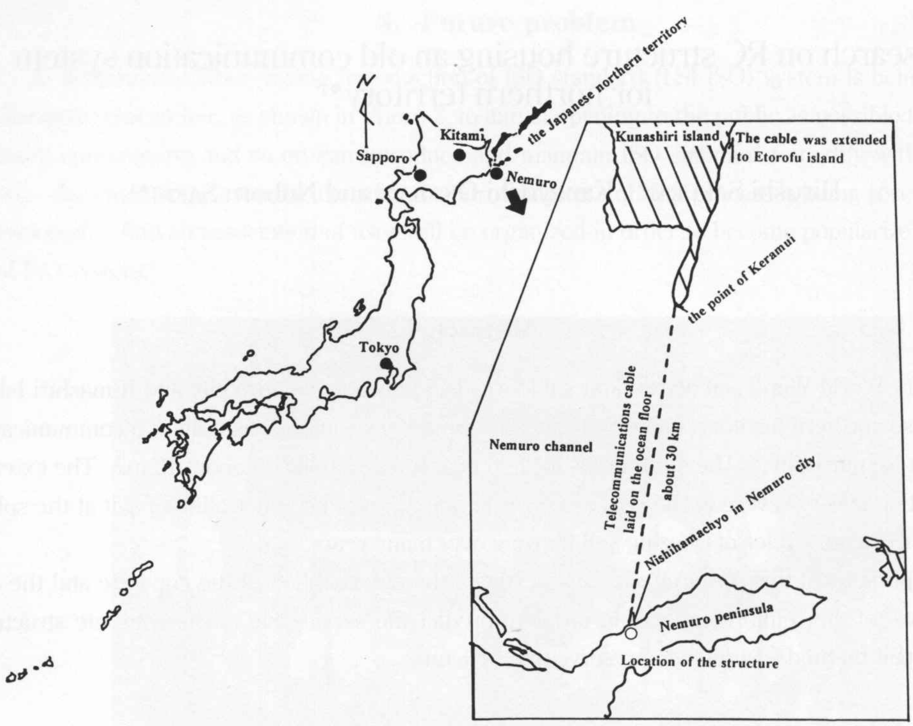

Fig. 1 Location of structure and the laid ocean cable.

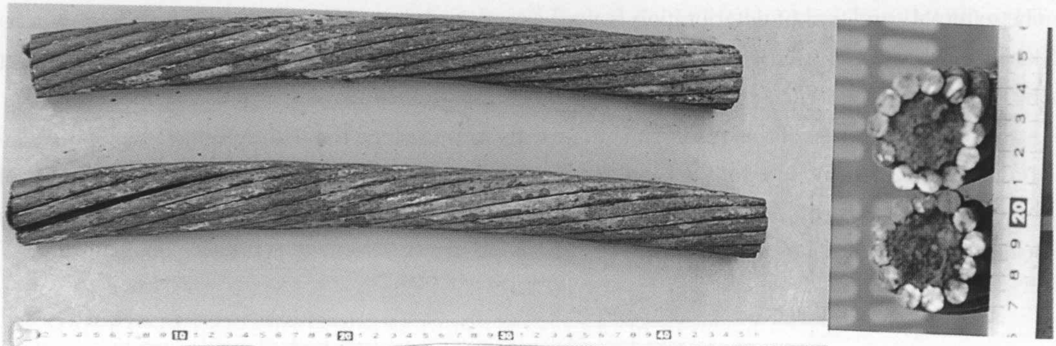

Photo. 1 A piece drawn up of ocean floor cable laid for telecommunications between Nishihamachyo in Nemuro city and the point of Kemurai in Kunashiri island

Photo. 2 The old communication system for Northern territory and the gate posts

Photo. 3 Okhotsk Sea behind the structure at about 12 m from the beach line.

2. Method

The research method is shown in Fig. 2.1. In the first step, the deterioration level is investigated by applying a nondestructive test method, such as the Schmidt hammer test, as shown in Photo. 4. For detailed study, chloride ion content and pH were measured at each depth by sampling with drill as shown in Photo. 5. The drilled hole is repaired using of fibrous repair material (Lion GRLC) as shown in Photo. 6, 7 and 8. Their each side of the structure is measured in order to grasp the influence of sea breeze and the freeze-thaw by sunshine in winter. The depth and arrangement of steel are measured by radar detector (Iron seeker) as shown in Fig. Photo. 9. Other studies conducted in parallel (on the right side in flowchart) is to research historical data of the structure in order to learn when the structure was constructed and to research the interest of the residents to preserving the structure as a landmark. In the next step, evaluation of soundness, prediction of remaining service life and repair consideration of the structure are researched.

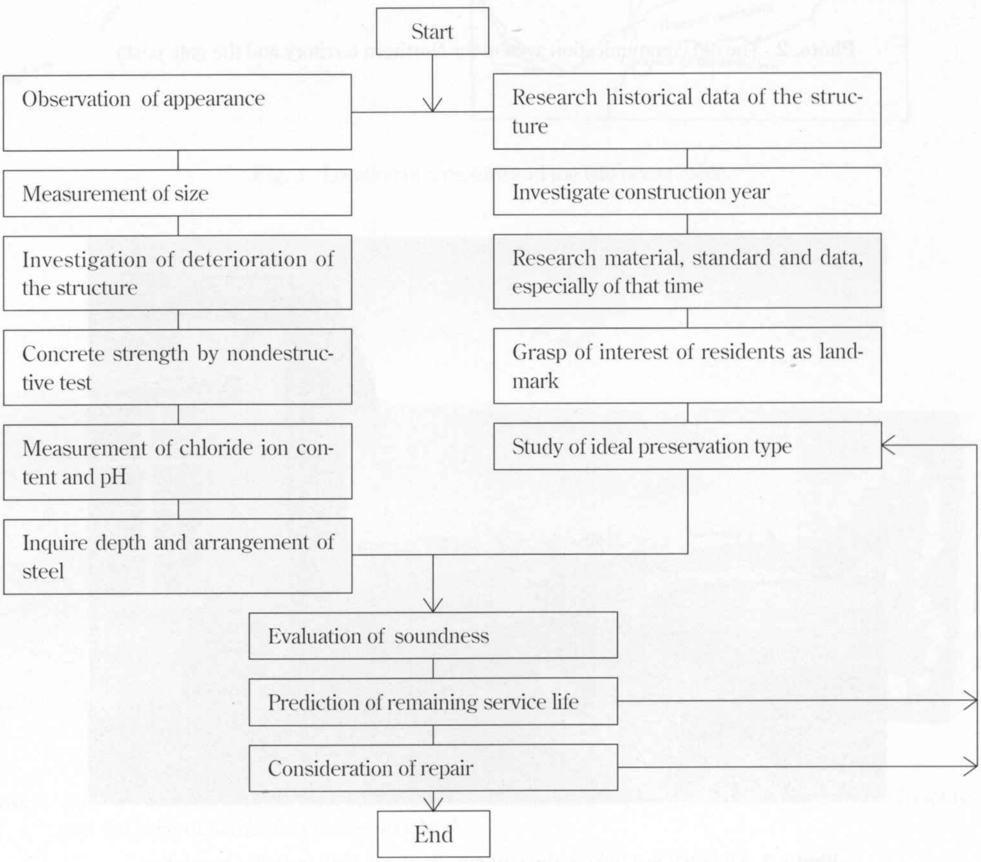

Fig. 2.1 Flowchart of this study

Photo. 4 Schmidt hammer test on face of external wall

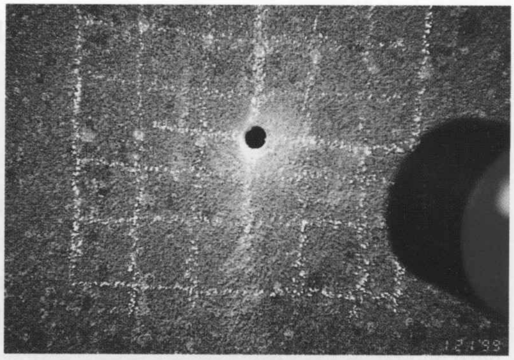

Photo. 5 Sampling drill hall in order to measure chloride content and pH, and observation

Photo. 6 Repair material for drilled hole

Photo. 7 Repairing hole

Photo. 8 A spot at Schmidt hammer and sampling

Photo. 9 Checking the depth and arrangement of reinforcing steel

3. Result

3. 1. 1 Observation of appearance

(1) Outside appearance of the structure

The mortar covering the exterior wall, whose high strength is shown in Fig. 3.1.1, had been protecting the concrete against frost and salt damages. The concrete in the building frame seems be made up of small units, by hand mixing or by using very small mixer because there several dense layers of coarse aggregate, each 30 cm thick. The coarse aggregate of the concrete is fully hard and black because there is rare break down and rare pop out by frost damage.

The edge and corner mortar of the exterior wall, concrete of the building frame and concrete of the lean-to roof were deteriorated and delaminated due to frost damage, especially at the south and west sides (as shown in Photo. 10,11,12 and 13), because the sides and edge (as shown in Photo. 14, 15, 16, 17, 18, and 19), sustained many freeze and thaw cycles as a result of sunshine and change of temperature in winter.

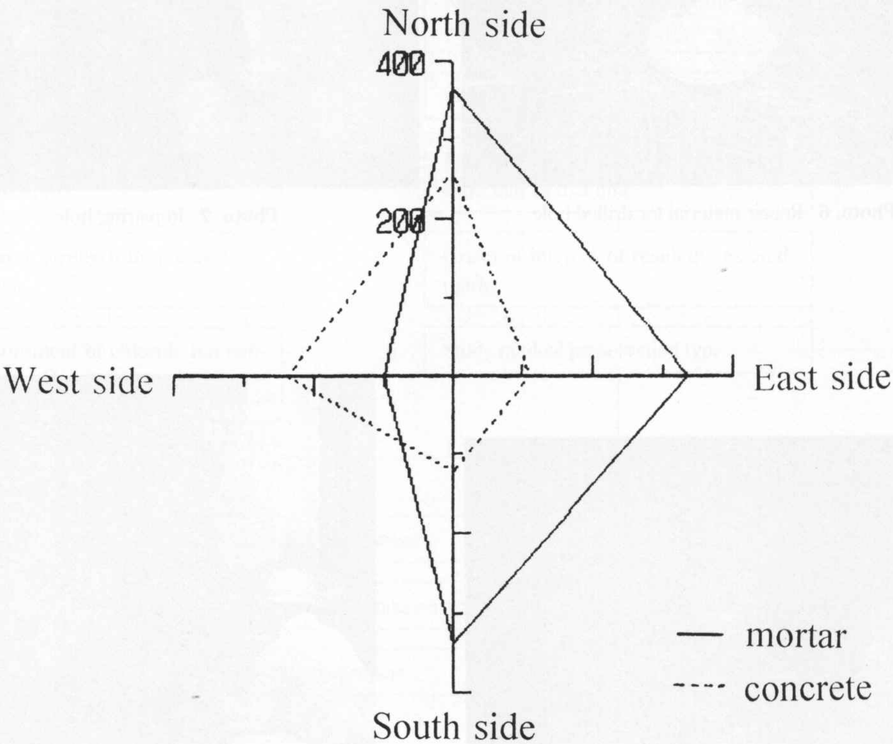

Fig. 3. 1. 1 Strengths of mortar and concrete obtained on each side wall by means of Schmidt hammer.

Photo. 10 The south side which has deteriorated due to many cycles of freeze and thaw with sunshine in winter

Photo. 11 The west side which is deteriorated due to many cycles of freeze and thaw with sunshine in the afternoon in winter

Photo. 12 The north side which has deteriorated comparatively light

Photo. 13 The east side which has deteriorated comparatively light

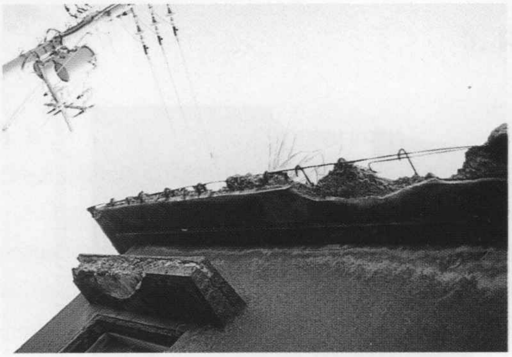

Photo. 14 Deterioration of lean-to roof on the west side

Photo. 15 Deterioration of lean-to roof of vestibule of on the south side

Photo. 16 Corrosion of steel in shallow depth under a window on the west side

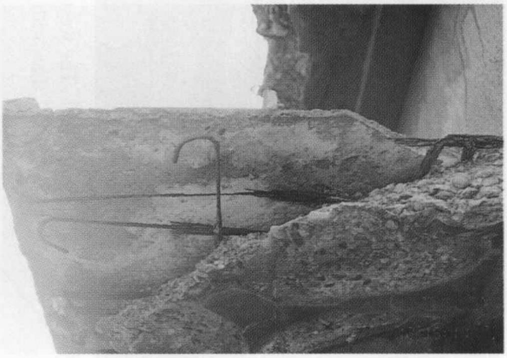

Photo. 17 Exposed steel due to scaling and spalling concrete of lean-to roof of vestibule

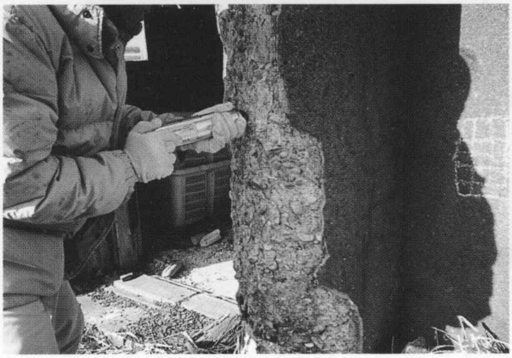

Photo. 18 Low repulsion of deteriorated part

Photo. 19 Spolling of deteriorated part

(2) The interior condition of the structure

Leakage or frost damage on interior wall was not observed inside the structure, as shown in Photo. 20, 21, 22, and 23. The plaster has remained comparatively intact because of the finish with fibrous lathing which seems to serve as heat insulation and prevent internal condensation. There is no diagonal tension cracks although the structure had suffered from large earthquakes such as 1993 Kushiro-oki earthquake and 1994 Hokkaido-toho-oki earthquake recently examples, because solid wall girders and a ceiling girder at the center of the interior, 4 quoin posts at each corner, and a partition wall between main room and cable-pit room were installed to support the ceiling in the one-storied building as earthquake proof measures, as shown in Photo. 21 and 22.

(3) Coastal revetment surrounding the structure

Coastal revetment surrounding the structure, which seems to have been constructed at the same time as the structure because it is of the same construction type with same reinforcing steel and mortar regardless of no reinforcing and mortar such structure in generally at recent years and it has the same faded-out appearance as the structure housing to old communication system, has deteriorated severely but is still functioning just to serviceability limited state as shown in Photo. 24, 25 and 26. The coastal revetment faces north, suffering impact of direct waves and splashes. Although the condition of external deterioration factor is due mainly to splashes, waves, and freeze-thaw cycles and several large earthquakes, the coastal revetment have stood up to the very severe external condition for more than 75 years. The same length of time as the structure housing the communication system. There are cracks at about 2 m intervals as shown in Photo. 26, which occurred during the early time of construction (which still happens sometimes with present construction, due to shrinkage or hydration heat) the parts surrounding the cracks are deteriorated and scaled by frost damage with due to penetration of water into cracks, but the reinforcing steels controlled the damage from progressing and preventing collapse. Also, with careful engineering philosophy, the use of stones as back-fill material of coastal revetment relieved frost heaving behind soil in winter.

3.1.2 Strength and chloride content of concrete

The strength of mortar and concrete of the structure housing the communication system obtained by means of Schmidt hammer at each side wall are shown in Fig. 3.1.1. The strength of mortar is from 360 kgf/cm^2 to 100 kgf/cm^2 stronger than concrete which is from 250 kgf/cm^2 to 120 kgf/cm^2, expect the west side. The strength of concrete and mortar on the north side are the strongest because of fewer freeze and thaw cycles than the other side. Greater mortar strength is advantageous for protecting concrete as shown in Photo. 25.

Chloride content at each side wall is shown in Fig. 3.1.2. The chloride content is pretty high more than about 0.2% lessening at deeper concrete layer. The north side, which faces the sea has more chloride content than the south side. The level of chloride content generates steel corrosion, especially at shallow depths of concrete cover. The pH is detected high level but the test will be tried again because the sample is a little.

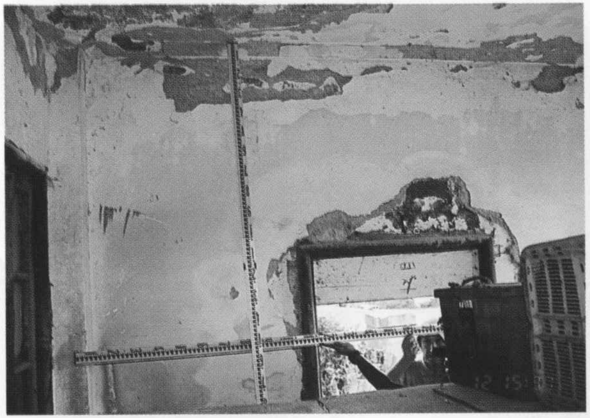

Photo. 20 Plaster finished wall and plastered ceiling without leakage for a long year and quoin posts inside in the south side

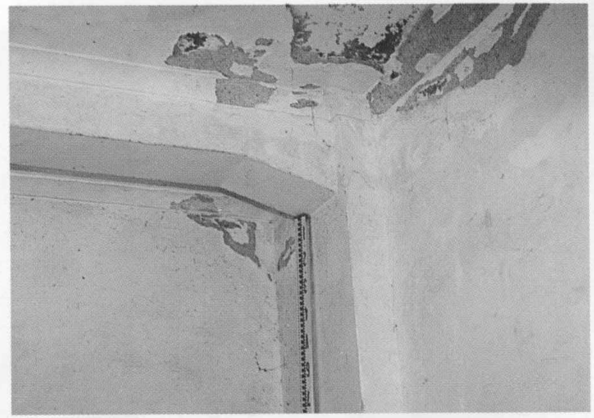

Photo. 21 Solid wall girder, ceiling girder and a partition wall between main room and cable-pit room at the center of the interior comparatively one-storied building, as measure fore earthquake proofing

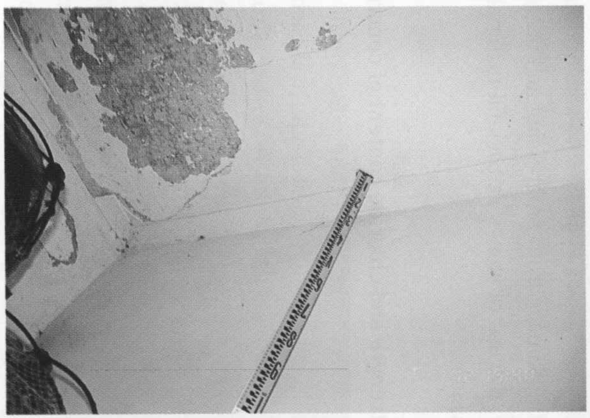

Photo. 22 Comparatively beautiful plaster and concrete on ceiling and partition wall in cable-pit room without leakage for long year.

Photo. 23 Plaster finished wall and plastered ceiling at the west side in cable-pit room where insulators are installed.

Photo. 24 Coastal revetment surrounding the structure, which is estimated to have been constructed at the same time, but this side is the present days.

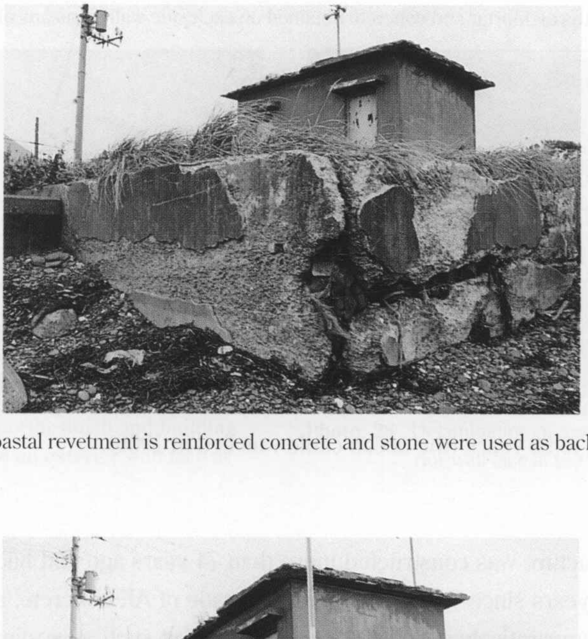

Photo. 25 Coastal revetment is reinforced concrete and stone were used as back-fill material.

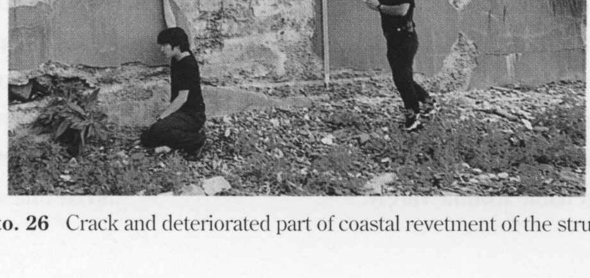

Photo. 26 Crack and deteriorated part of coastal revetment of the structure

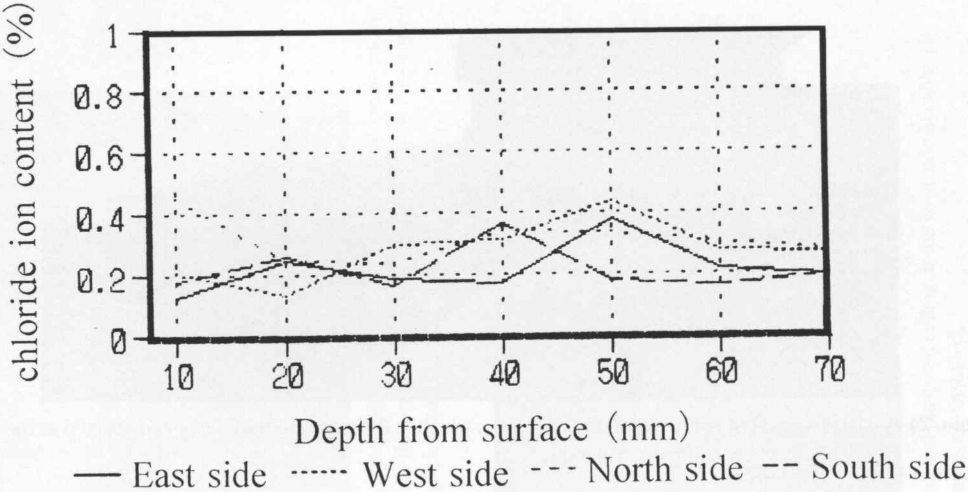

Fig. 3.1.1 Strengths of mortar and concrete obtained on each side wall by means of Schmidt hammer.

3.1.3 Research of historical data

The construction date of the structure is unknown because there is no design or construction data. There are two opinions : that it was is constructed at the end of the Taisho era circa 1925 because the structure has sufficient number of girders installed to secure earthquake proofing after 1923 Kanto-Daisinsai earthquake, and the second is that it was constructed at the same times as ocean cable was lied. The passage of time since construction range from 74 years, (which is about 1925, given the evidence of the owner who has been lived their since boyhood and the sufficiency of earthquake proofing), to 99 years (the ocean cable was lied in 1900).

3.2 Consideration

Although the structure was constructed more than 74 years ago and had not undergone maintenance for about 54 years since World War II is not made of AE concrete, and has suffered some large earthquakes, comparatively speaking, the deterioration such as scaling and delamination of concrete in building frame at exterior and mortar of exterior wall has stayed at serviceability limit state level requiring repair before the onset of the ultimate limit state level.

It seems that the design of the structure and the coastal revetment surrounding the structure, whose section of the coastal revetment is rather thinner than the present design without reinforcing as shown in Photo-24, the construction, and the choice of building material such as concrete, finish mortar, reinforcing, and back-fill stone were excellent at the time when there were some restriction on internal deterioration factor control such as nonexistence of AE agent even if at present with cases happening non-reliable trouble rarely.

4. Future problem

Detail measurements of concrete such as analysis of mix proportion, XRD, SEM and EPMA are needed. The date of construction has to be settled based on historical facts, an instrument such as insulators, materials such as reinforcing steel, wood growth ring and so on.

The structure and coastal revetment surrounding the structure are at a severe level of the serviceability limit state, nearing the ultimate limit state until some years as shown in Photo. 27 and 28. Repair that electric protection, desalinization of building frame concrete, reinforcement not relying on existing reinforcing steel, or corrosion prevent for exterior surface have to be enforced as soon as possible is demanded in decision by the former northern territory island residents and especially the residents in Nemuro city, that the structure be preserved in as the present condition, just berore abandon to communicate for northern territory or the completing construction.

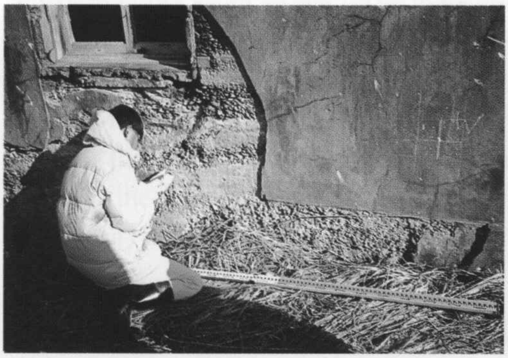

Photo. 27 Delaminated mortar finish and building frame concrete on exterior wall face at the west side

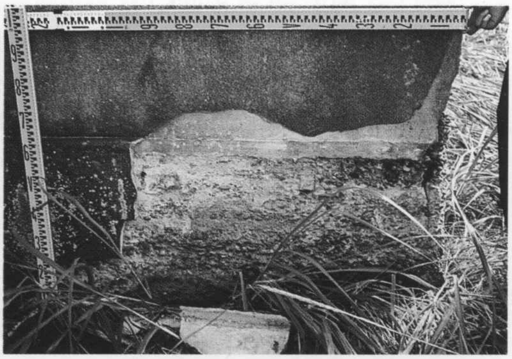

Photo. 28 Delamination of mortar progressing on exterior wall face at the west side

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