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Review of Different Repairing Methods on Sheet Pile Wharves

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ABSTRACT

Marine and coastal structures such as wharves due to extraordinary costs in construction, design and specific operational problems are very important. Therefore, the attempt is to conduct periodic inspections, care and rehabilitate facilities timely that will increase the life of structure. In this study, we investigate the type of damages on sheet pile wharves around the world. Finally appropriate ways have been used to resolve this failure checked. The outcome of these discussions will be familiarity about type of repairing methods that can identify advantages and disadvantages as a comprehensive source.

KEYWORDS: marine and coastal structures, repairing, damage, sheet pile wharf, method

1. INTRODUCTION

Marine structures are among structures that are exposed in complex marine environment situation. Choloride diffusion is one of the main damage factors that happens due to severe ground and ambient salinity and large fluctuations in temperature which reduce life of concrete sheet pile wharf. So, protection of concrete sheet pile wharves against carbonation and choloride penetration is very important[1]. Corrosion, overloaded and etc. are influential the wharf failure, spent on the steel sheet pile wharves[2,3]. Other cases which are influenced in wharf failure are: the impact of the ship, erosion, sedimentation and earthquake. In the following, we investigate actions that occurred on types of wharf failure in all over the world.

2. Investigating of examples on sheet pile wharf failure

In this paper, we study the following wharves:

- Elwood California wharf at U.S.A
- U.S. Naval civil engineering studies
- IOWA state university and U.S. Army construction engineering studies
- Tuzla and Haydarpa wharves at Turkey
- Akita wharf at Japan
- Haifa wharf at Israel
- Khent wharf at Belgium
- MayportNaval station at U.S.A

2.1. Elwood California area wharf

The first studies on wharves related to Shaufele's research[4]. He explained his investigation as a result of field observations between 1929 and 1935 that was presented in Elwood California area. Comprehensive strategy solution against corrosion which he spent in sheet pile wharves was covering steel sheet pile against oxidation and applying galvanized hardwares.

2.2. U.S. Naval civil engineering studies

The study was conducted on eight ports (Coco Solo, Key West, Puget Sound, Bremerton, Pearl, Norfolk Alameda and San Diego) [5]. The purpose of this investigation was to compile sufficient data to improve the design and construction of future installations as well as to have factual information which can be used for estimating the service life of existing and possible future installations.

A primary objective of this study was to determine whether cathodic methods of protecting piling justify the expense of a cathodic protection system.

The following results were obtained from the evaluation of the 8-ports:

- The maximum rate of corrosion occurs in the splash zone about 2 feet above MHW.
- Cathodic protection is considered an effective means for protecting the areas of steel piling that are constantly wet. The extent to which the protection carries into the tidal and splash zone has not been completely defined.

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- A protective coating applied along the full length of a pile before driving increases the life of the pile especially from MLW into the Mud zone.
- Protective coating used along sheet pile increases life especially from MLW into the Mud zone.

2.3. IOWA state university and U.S. army construction engineering studies

Before the 90s, for much of its early history, the US Army Corps of Engineers concentrated on designing and constructing new facilities. But now the mission of the Corps is shifting from construction to maintenance of existing facilities. As part of the Repair, Evaluation. Maintenance, and Rehabilitation (REMR) program, this research focuses on the evaluation and repair of the steel sheet pile structures within the Corps' Civil Works projects[6].

The objectives of this work were to (1) develop an inspection and rating system that uniformly and consistently describes the current condition of steel sheet pile structures, and (2) develop guidelines for the maintenance and repair of these structures.

Inspection data are entered onto a computer disk through a PC program that summarizes the safety and serviceability problems associated with the structure. By supplying the initial costs, expected life, downtime costs, interest rates, and inflation rates, an experienced engineer can make a preliminary maintenance and repair plan for the structure.

2.4. Tuzla and Haydarpa wharves at Turkey

In the life cycle of port structures, devastation by an earthquake might be a rare event. However, once it occurs, the magnitude of the consequences will be so large that the effect of earthquakes can be a major issue of national interest.

The reconnaissance was carried out as a cooperative research from September 1 to 5, 1999 by JICA team and from to 10, 1999 by JSCE team. The objective of their reconnaissance was to obtain and compile the near field earthquake motions[7].

This is a preliminary report. It compiles earthquake, structural and geotechnical data including preliminary discussions, but does not contain detailed analysis.

The Haydarpa port is located 90km northwest of the epicenter. The estimated peak ground accelerations were 0.05 to 0.1g. Damage to this quay wall is generally minor.

Tuzla port is located around 60km west of the epicenter. Horizontal displacement of structure and settlement occur about 0.1m.the most severe damage can be noted in these ports are severe liquefaction. Improving soil for embankment is an effective way to increase performance of sheet pile walls during the earthquake. In these wharves, residual strength inspection was also considered.

2.5. Akita wharf at Japan

Representative damage to a sheet pile quay wall is shown in Figure 1.This quay wall was located in Akita Port, Japan, and shaken by the 1983Nihonkai-Chubu earthquake. The damage was mainly due to large pressures applied to the sheet pile wall by the liquefied backfill sand[3,8]. The sheet pile bending moment became excessively large, resulting in the opening of a crack in the wall. This quay wall subjected to ground motions of similar intensity. The anchor was embedded in liquefiable soil, resulting in deformations in the entire wharf. Example indicates that the mode of damage can differ significantly according to the geotechnical and structural conditions of a sheet pile wharf.

Fig.1. Damage to a sheet pile quay wall at Shimohama Wharf, Akita Port, Japan, during the Nihonkai-chubu earthquake of 1983.

2.6. Haifa wharf at Israel

In 2004, Vladimir Chernov understood that repairs of sheet piles in the tidal zone should be designed as an integral component of a larger system of corrosion protection of bulkheads. The corrosion within the actual tide range is

relatively mild. However, the rates of atmospheric corrosion just above MHW may be as high as the highest galvanic corrosion rates underwater[9].

There are three well-known types of sheet piles protection above the water:

- Protective coating, applied in dry using caissons
- Addition of protective welded steel patches
- Extension of pile cap across the exposed steel zone below MLW

In this wharf, Chernov paid attention to durability and understood that the use of Self-Compacting Concrete(SCC) reinforced with Structural Synthetic Fibre (SSF) helps to eliminate these problems.

Figures 2 and 3 show the lower and upper part of the form work is mounted to sheet piles in Ashdod project.

Fig.2. The lower part of the formwork is mounted to sheet piles

Fig.3. Theupper part of the formwork is mounted to sheet piles

2.7. Khent wharf at Belgium

Study in relation to corrosion, as well as impact of the ship and liquefaction is in Khent port[10]. The quay wall was built Z- shaped with copper alley and iron. In 70 AD, and before the end of 10 years of construction, severe corrosion was found in the sea walls. In 1978, a severe corrosion rate compared with the thickness of plate. 25-year protection strategy is presented with using coating system, adding reinforced steel patch and improving soils with increasing ϕ. Below figures(4 and 5) show the ground settlement in liquefaction and damage to the wharf.

Fig.4. Ground settlement in liquefaction

Fig.5. Damage to the wharf

2.8. Mayport Naval station at U.S.A

Including the latest research in the field of sheet pile wharf damage is related to M.R Mozos' study about Mayport Naval station[11]. The Mayport Naval Station in Mayport, Florida consists of seven wharves, and is used for homeport berthing functions and munitions loading. The project described herein focuses on the improvements and upgrades to Wharf Charlie 1, located on the north side of the harbor. The original Wharf Charlie 1 berth consisted of 185m of steel sheet pile diaphragm cells built in 1952. In 2008 an above and below water condition assessment inspection was conducted, and identified the following structural issues: 1) widespread corrosion with pits and holes up to 305mm in diameter were observed in the steel sheet piles with the majority of corrosion below the concrete cap around the midline, and 2) sinkholes noted in the deck adjacent to the sheet pile wall, likely associated with backfill migration through the corroded sheet piles.

As a result the new wharf was procured as a design/build project. A design was developed for the new wharf, which allowed the existing foundation elements to be left in place during construction. However, in leaving the existing foundation elements in place additional difficulties were created. The new foundation elements, such as the new bulkhead dead man anchor system, upper deck foundation, and ship's service utilities had to be positioned to avoid conflicts with one another and with the existing structural elements that were left in place.

The new design consisted of a combination king-pile/sheet pile wall driven outboard of the existing diaphragm wall, with the space between the two backfilled with flowable concrete fill. The design primarily utilized traditional limit-equilibrium methods to design the wall ignoring the effects of the existing structural elements. However, given the complex behavior of the existing elements with the new wall system, advanced continuum soil analyses were also conducted to better understand the behavior of the complex system and confirm acceptable performance.

Figure 6 shows partially excavated cell.

Fig.6. Photo of Partially Excavated Cell with Upper Deck Foundation Piles.

3. Conclusions

1. According to investigation of different sheet pile wharves samples in all over the world, the main causes of damages are: erosion, sedimentation, impact of the ship, aging structure, earthquake and soil liquefaction

2. Different methods for repairing sheet piles wharves were expressed: covering sheet piles against oxidation, cathodic protection, improvement soil for embankment, use of steel jacket, use of self compacting concrete (SCC) reinforced with structural synthetic (SSF), add reinforced steel patch (SSF) and combination king pile/ sheet pile wall.

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