Analysis of jacket pile failure at breasting dolphin pile on berthing dolphin system

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Abstract. The study evaluated the structural damage of the jetty pile jacket due to the impact load within operation days. The pile jackets on breasting dolphin (BD) were destroyed in front of pneumatic floating fender or leaning back direction. It observed that the failure was due to an impact load perpendicular to the pile and shear load between the floating fender and the pile jacket. The polyolefin material for pile jacket is not designed to hold any impact load from pneumatic fender vertically during docking. The pile jacket was installed to protect against to corrosion attack between tidal and splash zone. While the coal barge is docking on the jetty, the floating fender will crash and push the pile jacket by impact load at about 13.88 ton.m and swing press perpendicular to the breasting dolphin pile or shear load vertically. The installation of rack fender may practically protect the breasting dolphin pile and back up currently pneumatically floating fender and the jacket pile.

1. Introduction

The Barge Loading Conveyor (BLC) is a construction facility on the seaside to distribute the mined coal from the stockpile into the barge. The BLC system consists of Trestle, Jetty, Mooring Dolphin (MD) and Breasting Dolphin (BD). As an illustration, the Barge size of 300 ft has 90 m length, 24 m width, and 800 tons maximum capacity [1]. The main construction of BLC consists of the upper structure (steel beam) and steel pile. Generally, the BLC system is made of carbon steel ASTM A252 grade 2 for the upper structure (wide flange beam) and the pile pipe of ASTM A252 grade 3 [2]. Mostly problem in the steel structure is corrosion attack. The atmospheric environment with a high salinity of seawater will enhance oxygen dilution to promote corrosion rate to the steel structure.

The expected life of BLC system up to 25 years needs corrosion protection systems to control and to inhibit the corrosion rate until a minimum level through a proper coating application, cathodic protection, pile jacket installation, or its combination [3]. The application of the corrosion protection methods prioritized on the critical area of the jetty by considering the risk assessment analysis. In this study, not only the coating quality was improved, but also the pile jacket installation has applied. Installation of pile jacket will cover trestle, jetty, mooring dolphin areas. However, it observed that the breasting dolphin (BD) area shows the torn and fracture damage, especially on the pneumatic fender (floating) area as an area to backrest the barge while leaning back. The typical specification of the used pneumatic fender, Yokohama 80 (metric) before aging has 50-60 durometer hardness type A, the 18 MPa Tensile strength of and 400% or more elongation. The tear resistance of this fender is 400 N/cm. The root cause of the pile jacket failure needs further evaluation to find the best way to resolve this typical failure [4].

The pile jacket as a tidal warp protects the tidal area of any steel structure, concrete or timber (Figure 1). Tidal warp has an advantage when a structure condition is difficult for epoxy coating application or other conventional application of the protection system. Tidal warp system isolates against to any oxygen and water and also inhibits corrosion rate on the metallic surface, concrete or timber.
The pile jacket system consists of special tape surrounding the pile and was wrapped, for example, with Enviro Jacket (HD 6060) [6]. This Petro tape consists of non-woven synthetic fiber embedded and coated with petrolatum base material and inert filler compound. The Petro Tapes is practically plastic and stable, that capable of absorbing any vibration sources. This tape is resistance against mineral acid and alkaline. The nominal thickness of this tape is 1200-micron min. While the Enviro-Jacket HD 6060 consist of 100% Virgin Polyolefin with UV Stabilizer as a new uniform protector, free from a contaminant, oil, and grease, wrinkles pinholes and other flaws. The typical pile jacket size is typically 60 mil thickness, UV resistance of 90%, puncture resistance of 400, and trapezoidal tear resistance of 590 N.

2. Method
The failure analysis in this study covers evaluating the main parameter that role in the mechanism of jacket pile damage and identifying the root cause of tear and fracture of damaged jacket pile either related with the operational activity in the field or any mistake of the used material or other parameters related with fabrication and installation of pile jacket. The next step is to eliminate undesired failure to avoid possible repetitive damage in the future. The failure analysis on breasting dolphin area involves (a) observation, and visual inspection includes documentation digitally, (b) review the impact energy against to fender and breasting dolphin pile, and (c) recommendation to resolve typical damage.

3. Result and discussion
The lean back system of the steel jetty in this study is the dolphin type. Dolphin type is a construction system that is designed to hold any impact load and to tether the barge. Jetty is attached with dolphin system to hold barge impact to avoid any failures between barge and jetty, after tightening.
Barge to the breasting dolphin. Breasting dolphin has a larger size to enable holding any impact load and attached with fender and holder for lean back purpose [7,8]. While mooring dolphin is not purposed to hold any impact load of the barge. The barge is typically equal to 9700 DWT, which has immersed the body of 5.7 m depth, the unmerged body of 1.25 m height. With the length of 90 m and 24.5 m width, the barge leans at the velocity of 0.15 m/s. The impact energy of the barge can be calculated referring to the seawater density of 1.03 kg/dm³, in which, the impact energy to the barge reaches up to 13.88 tons.

The fender system roles to avoid any damage for barge and jetty, while the barge docks to breasting dolphin BD, if any possible impact load, shear and pressure load between the barge and breasting dolphin. The impact force causes possible damage to barge and jetty structure. Possible damage is undesired, in which the area in front of the breasting dolphin side should be attached by fenders that can absorb any possible impact energy (Figure 2).

![Figure 2. Impact force horizontally and vertically shear force.](image)

The on-site investigation conducted, and its result compared with simulation analysis. The impact energy between barge and fender, also between fender and BD pile jacket reaches up to 13.88 tons. In this case, the used material of Enviro 6060 (polyolefin) was unable to hold the huge impact load perpendicularly (horizontal direction) and shear load (vertical direction). That the pile jacket damage occurs only at BD pile jacket area that directly contacts with pneumatic fender (floating). The direct interaction of impact load and shear load between the pneumatic fender and BD pile jacket may act as the main cause of the tear and fracture damage of pile jacket [9,10].

It is recommended to employ additional guard or fender in the form of rack structure to protect the corrosion system of BD pile from any impact force and direct shear force from the pneumatic fender. The rack fender installation does not need to replace currently fender system, i.e., pneumatic fender (floating). The rack fender roles as an additional guard to protect the pile jacket and other corrosion protection system of BD pile. The fabrication and installation of rack fender considered as more effective and efficient. Even, the pile jacket can be installed first, it before installing the rack fender (Figure 3).
4. Conclusion
The field observation result has compared with the simulation result, in which, the BD pile jacket damage occurred due to the impact mechanism horizontally and shear force vertically. The material strength of pile jacket cover of Enviro 6060 is unable to hold impact energy at about 13.88 ton.m and shear force to pneumatic fender while the barge is leaning back. The pile jacket was destroyed due to limited capacity to hold impact energy while the barge is leaning back. The pile jacket is purposed to protect corrosion attack to the pile surface on the splash zone area and does not intended to hold any impact force from the pneumatic fender. The installation of the local rack fender for the breasting dolphin pile roles as an additional guard to protect the pile jacket and the corrosion protection system.

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