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Press-in technology: Advantage of Gyropress method for renovation of the third wharf of Dakar Port in Senegal

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ABSTRACT: Dakar Port, located in Senegal, is the second largest port in Western Africa behind Abidjan. It serves as a transit port to inland countries for 14% of its capacity. The 3rd wharf constructed in 1939 was reserved for the Republic of Mali under a bilateral agreement. However, the transit volume of goods had increased 2.5 times from 2010 to 2015 and is expected to continue to increase. The increase in the volume of seaborne goods has caused considerable deterioration of the wharf, which may lead to its collapse. Moreover, large vessels are constrained by draught. This paper describes the construction methodology, named the Gyropress method, used to repair the 350m long quay of the wharf. With the Gyropress method, tubular piles are pressed and rotated with the assistance of cutting ring bits attached to the pile toe. Moreover, berthing and vessel unloading at the wharf were not interrupted during construction.

1 OUTLINE OF THE PROJECT

1.1 *Location*

Senegal is a small country in West Africa covering a total area of 196,722 km^2, sharing its borders with Mauritania, Mali, Guinea, Bissau Guinea, and the Atlantic Ocean, in the North, East, South, and West respectively. As of 2013, the population was about 13.5 million and it is expected to reach 25.7 million in 2035 (*National Agency for Statistic and Demography ANSD, Senegal 2013*). Senegal has a semi-arid tropical climate with a rainy season from June to September. Dakar, the capital city, is located at the westernmost point, toward the Atlantic Ocean. Dakar covers only 0.4% of the total area of Senegal, however, 23.2% of the total population is concentrated in this city.

1.2 *Project background and objectives*

The constant increase in the characteristics of the merchant, cruise and fishing, or even leisure vessels, in particular, the increase in their draught, as well as the demands on port operating equipment, often poses the problem of maintaining port activities, in the oldest harbor basins (*Nicolas R. 2014*). Facing this problem, the port managers have two possible solutions: Building new docks, or strengthening existing ones by increasing the quay depth. The construction of a new wharf is not usually a favorable option, due to the high cost of the project and a lack of space. Thus, port managers often turn to renovation. Quayside renovations are quite complicated due to the location. The quays are the area of loading and unloading of goods, essential operations on which depend several corporations. In addition, the site is often difficult to access so that it requires refurbishment from the seaside. Renovation from the sea is not a preferred option as it would have seriously affected vessel berthing and port operations.

The renovation from the sea could impact on the safety, efficiency, speed, and cost of the project. The structure of quays can be classified into three categories according to their method of construction: Quays on piles, retaining curtains walls quay, and gravity quays. The third wharf of Dakar Port (**Figure 1**) built by a concrete block is a gravity type. The method chosen for the renovation is the Gyropress method. The Gyropress method is an innovative construction method, used in several projects in Japan, particularly for the renovation of the Port of Nagasaki.

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Figure 1. Third Wharf of Dakar Port.
Map: https://google.co.jp/maps

1.3 *Geotechnical condition*

The geotechnical survey conducted onshore and offshore was allowed to identify three layers from the seabed as shown on **Figure 2**: Plastic and hard marl layer from 1 to 3 meters, a fractured grayish whitish limestone-marl with a moderately low compressive strength from 3 to 12 meters, and fractured grayish limestone moderately with low compressive strength up to 17 meters. The unconfined compressive strength of the marl and limestone-marl varied from very low to high strength (from 2.6 MPa to 68.8 MPa).

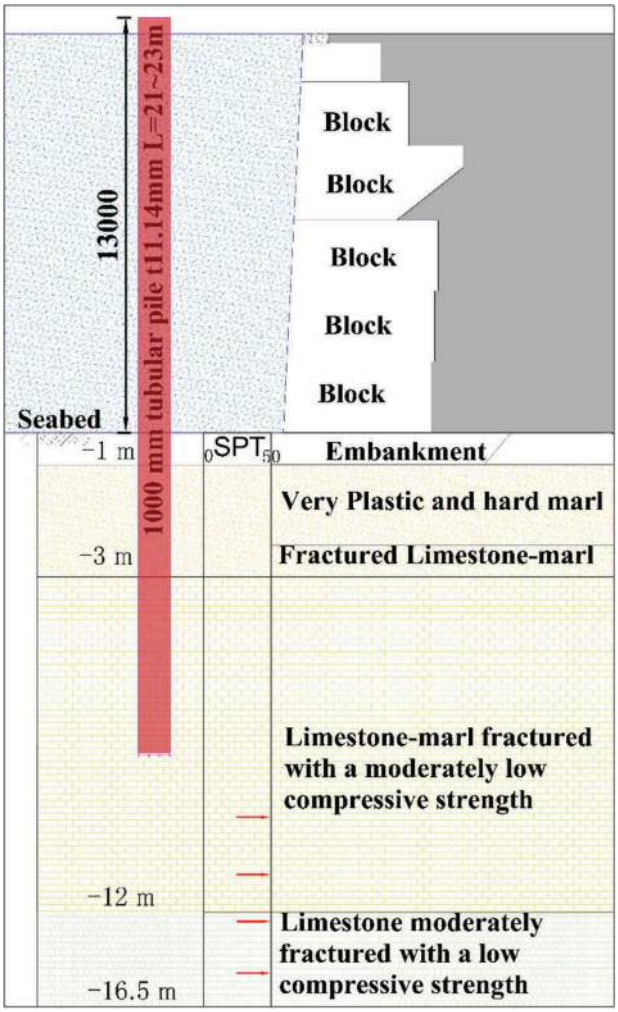


Figure 2 . Third Wharf soil condition.

2 STRUCTURE TYPE

Since the quay will be repaired to deepen the depth from -10.0m to -12.0m, for large vessels to berth, a new quay on the seaside was first considered. At the preparatory survey stage (*JICA, 2016*), the concrete block quay and quay on piles were selected as the structural type for the renovation of the quay based on the "Technical Standards for Japanese Ports and Explanations":

- ➢ Option 1: Gravity type: L-shaped Cellular block (square block) & Cast-in-place concrete **(Figure 3)**.
- ➢ Option 2: Tubular pile & self-supporting raker pile **(Figure 4)**.

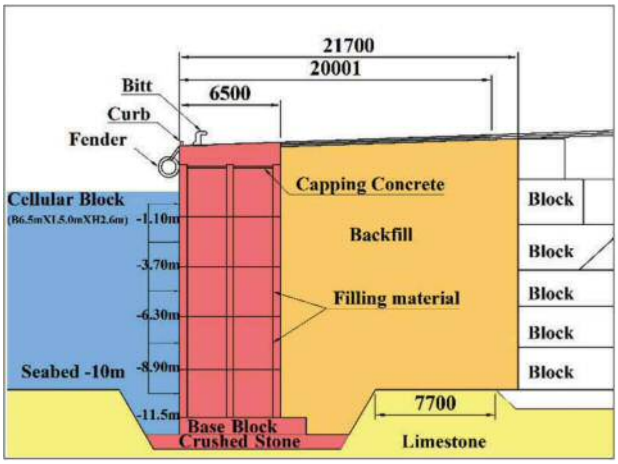


Figure 3 . Concrete block quay.

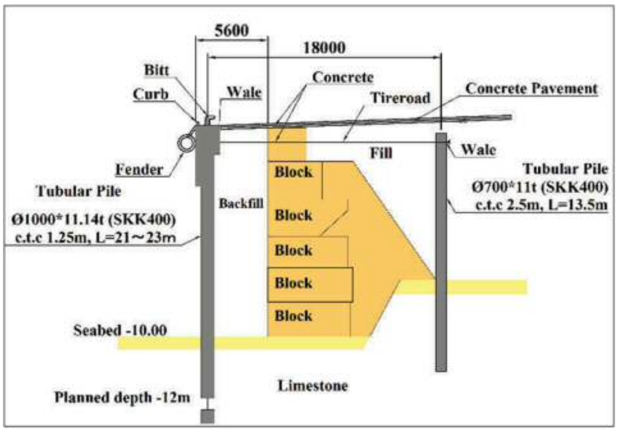


Figure 4 . Steel tubular pile quay.

As a result of the comparative examination, the gravity cellular block type quay was initially selected which was similar to the existing quay structure and was planned to be built about 22 m inside the bay from the existing quay. But there was concern that the distance to the opposite quay pier would be narrowed during operation, reducing maritime safety and convenience. In addition, the construction area was divided into two berths, and it was required that the impact on cargo destinated for landlocked countries would be minimized, even when one berth was under construction, by partially using the other berth. Therefore, in the detailed design, the concrete block was changed to a tubular pile type that can reduce the width of the quay inside the bay as shown on **Figure 4**. An additional soil investigation was carried out. The survey revealed that the ground in front of the third wharf was mainly composed of limestone marl and weathered limestone. After the soil survey, the Gyropress method and the All-Casing method were compared.

3 REASON OF SELECTING GYROPRESS METHOD

In the design stage, the large diameter bored pile with temporary steel casing commonly known as the All Casing method was proposed. However, this method would greatly impact the berthing and vessel unloading at the third wharf because it needs to use many working vessels from the seaside. As 95% of the total capacity of the third wharf is destined for Mali and other landlocked countries, stopping or slowing the port operations would have a big impact on those country's economies and food security. In addition, many vessels need to be involved so that, the construction speed and safety would become lower. For all reasons mentioned, the All Casing method and the Gyropress method were compared.

After making a comparative analysis, it was found that renovating the quay with the Gyropress method is more cost effective and needs less time. Moreover, the impact on berthing and vessel unloading could be minimized since it requires less equipment and fewer workers on site. After considering these facts, the Gyropress method was highly evaluated and adopted **(Table 1)**.

4 THE GYROPRESS METHOD

The Gyropress method used in this project is an innovative way for tubular pile installation. In Gyropress Method, a newly developed Silent Piler, called Gyro Piler is used **(Figure 5)**. It installs

Table 1. Comparison between Gyropress method and all casing method.

	Gyropress Method	All Casing Method
Overview	Due to the rotary cutting press-fitting, all processes can be performed on the steel tubular pile. For this reason, adjacent berths can be used even during the construction period, so there is little economic loss. In addition, it does not affect the water area facilities (berths, routes, etc.) in the port.	Using a work boat such as a guide barge or a pile driving ship, a casing is installed first. After placing the steel pipe pile inside, the casing grips it and rotates downward. An excavator is used to remove the crushed stone. This is a general construction method for port piers. Since the work will be carried out offshore by a work boat, the adjacent berths cannot be used during the construction period, so the minimum space is required in advance.
Machines	3 Machines: Gyro Piler, Crawler Crane, power unit.	7 Machines: Casing, guide barge, working barge, crawler crane, hoist ship, tugboat, anchorage ship.
Workability	Since everything is done on land or on piles, the work process and quality are not easily affected by weather and sea conditions. No special skills are required because general construction machines are used.	Work boats need to be circulated and towed. Since it is a work boat, the process and quality are easily affected by weather and sea conditions. It occupies a wide area by using work boats and mooring lines.
Safety	It does not interfere with traffic at sea because no work boat is used.	Due to the large number of work vessels, it is necessary to ensure the safety of vessels moving over the sea.
Environmental	Because it is a vibration-free and noise-free press-fitting method, it has less impact on the surrounding environment.	Since many work boats are used, there is concern about the impact on the natural environment and people.

Figure 5 . The Gyropress method.

tubular piles with cutting bits attached on pile toe by rotary jack-in system and travels on top of piles which are completely installed (completed piles), (*Giken, 2009*). Thus, piles are installed at the required depth with minimum noise and vibration. The removal of underground obstacles or earthed objects is no longer necessary. In addition, the Gyropress is an efficient construction method for space saving. Since the Gyro Piler has clamps that expand inside the piles, the machine can maintain itself, self-walk on completed piles, and install piles. A temporally working platform is no longer necessary and the total construction yard is reduced. Moreover, the Gyro Piler F401-G1200 used in this project is equipped with the Press-in Piling Total System [PPTSTM] technology that makes it possible to monitor the substrata ground conditions during piling work for scientific analysis. The piling data that gives feedback can be linked to borehole data to optimize the applied press-in force, auger torque, extraction force, and penetration depth for optimum and efficient piling operation work.

4.1 *Structural members*

This project required a high stiffness wall structure because the height of the wall after completion was 13 meters. Robust and stiff tubular piles were selected to ensure enough strength and capacity. The piles of two different diameters were used in this project: 1000 mm and 318.5 mm **(Figure 6)**. The number of bits attached to the 1000 mm pile was 10 units and 6 units for the 318.5 mm pile.

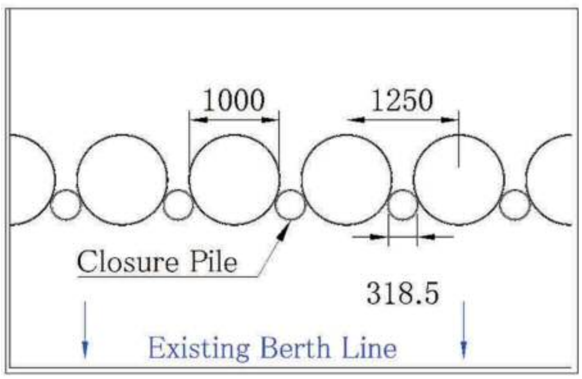
5 CONSTRUCTION SEQUENCE

The construction sequences of this project are described as below:

(a) 318.5 mm tubular pile with cutter bits

(b) 1000 mm tubular pile with cutter bits

(c) Piles Installation Process



(d) Tubular Piles Alignment

Figure 6. Photos of the Project.

1000mm and 318.5mm diameter tubular piles diameter were used to construct a 350m long tubular pile wall. The center-to-center distance between each 1000mm diameter tubular pile was 1250 mm. Between the 1000 mm diameter piles, 318.5 mm tubular piles (Closure piles) are installed to serve as particles protrusion protection **(Figure 6) (c)**. The Gyro Piler F401-G1200 used in this project has three clamps of 600mm height each, so they can ensure enough capacity and reaction force during installation. The method uses press-in and rotating force to install the piles, thus, the noise and vibration were kept low. The Gyropress method allows the piles to be installed even there was underground obstacle such as a very hard and plastic limestone marl layer. To prevent soil plugging at the pile toe, a water lubrication system was used. A small water steel pipe is welded inside each 1000 mm tubular pile as shown on **Figure 6 (b)**, then, was connected to the water lubrication system. The required water is taken from water tanks. The pile top is equipped with a swivel to prevent the small steel water pipe from being distorted during piling. At the initial piling, a steel cage grid of few meters long is placed next to the quay on the seaside, on which the reaction is placed **(Figure 8;10)**, then the reaction stand is loaded with counterweights on both sides. Thus, the Gyro Piler is assembled by setting the saddle in the reaction stand first, then the leader mast, and the chuck at the last step. As the diameter is small, the installation of the 318.5 mm tubular piles was facilitated with a water hammer as shown in **Figure 6 (a).** The quay length of 350 meters was divided into two sections during the construction work. One section was reserved for the berthing and vessel unloading while the other section was being constructed. **Figure 7** shows the plan view during the construction process. After setting the reaction stand at the middle of the section to be constructed, two Gyro Piler F401-G1200 were assembled one by one for the piling work from the left and right of the reaction stand respectively. A 90 tons crawler crane was used to lift and pitch tubular piles to each Gyropiler. **Figure 9** shows the cross section of the construction process. The tubular piles are pitched to the chuck of the Gyropiler one by one. The pitched tubular piles are then pressed and rotated into the ground. When the chuck reaches its full capacity to grip the tubular pile, the driving attachment is fixed to the pile top. Then, the chuck grips on the driving attachment and continues the installation process until the 1000mm diameter tubular pile reaches the required depth. After installing two 1000mm diameter tubular piles subsequently, the closure pile is installed in between (**Figure 11**). To fit inside the chuck, a joint member attachment is inserted into the chuck, then the 318.5mm diameter tubular pile is pressed and rotated to the required depth.

6 PRODUCTIVITY

While the berthing and vessels unloading were continued at the wharf during the piling work **Figure 12**), the tubular pile installation rate was maintained at 2.5 piles per machine per day on average.

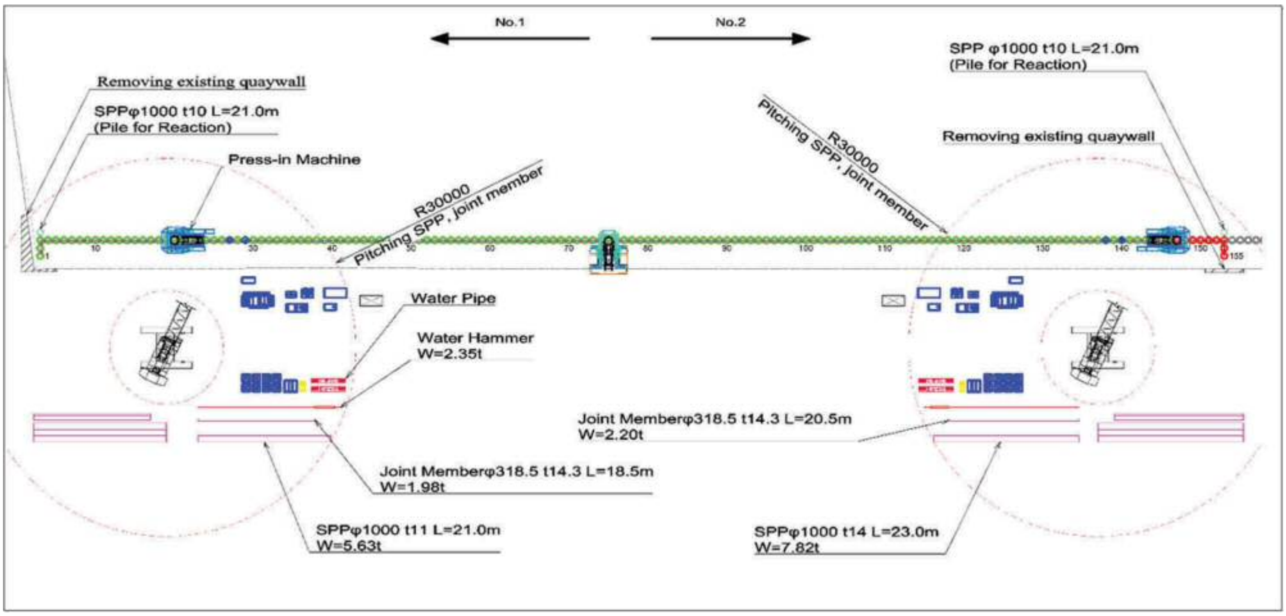


Figure 7 . Piling process: Plan view.

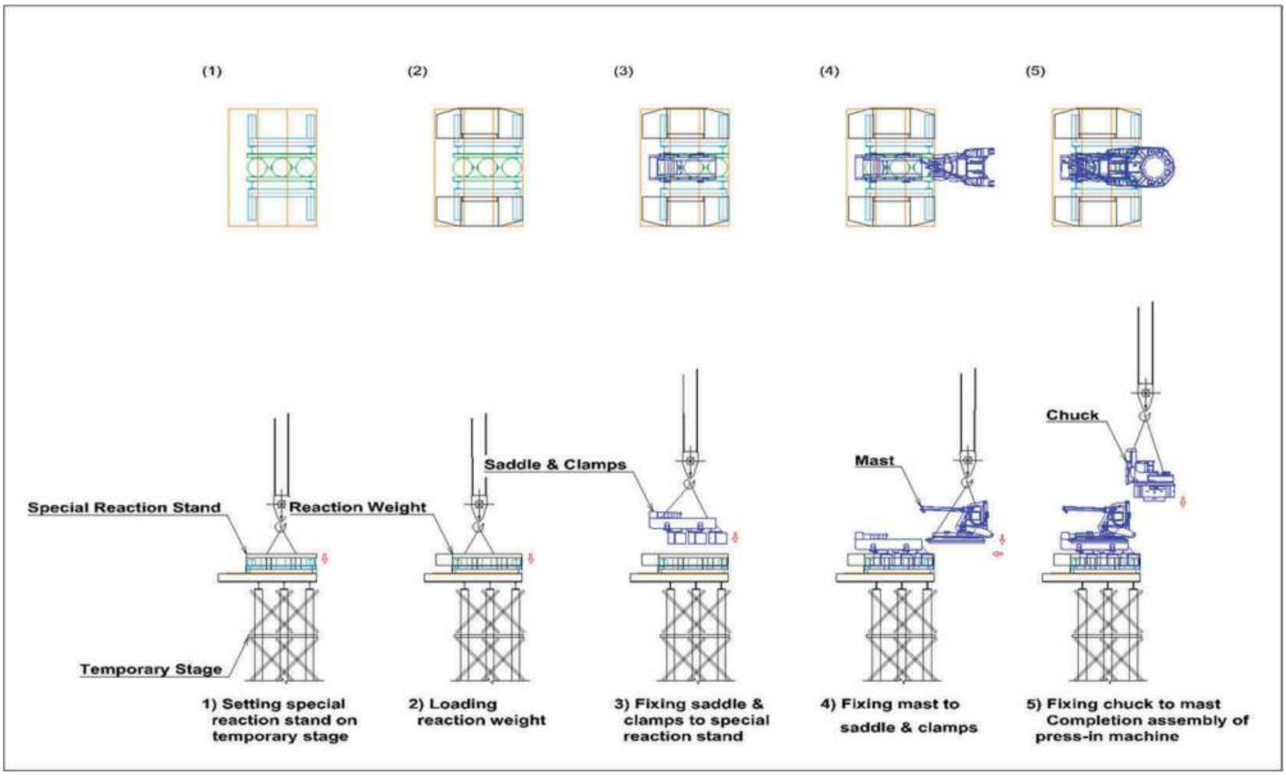


Figure 8 . Gyro piler assembling process (Upper: Plan view, lower: Side view).

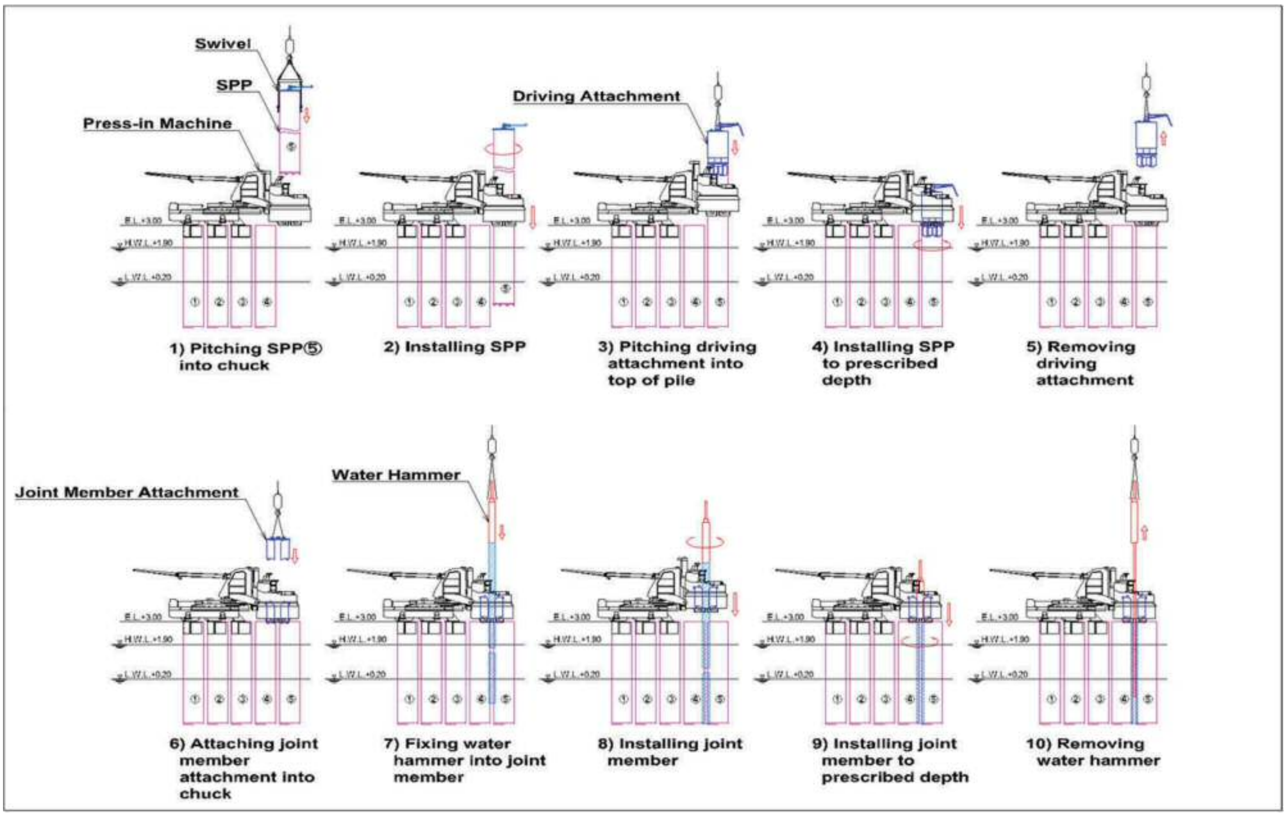


Figure 9 . Piling Process: Side view.

Figure 10 . Initial piling.

Figure 11 . Closure pile installation.

Figure 12 . Berthing during construction.

7 CONCLUSION

This project started in October 2013, in response to a request from the Senegalese government. The government of Japan agreed to provide technical and financial assistance for rehabilitation of the third wharf. The renovation work at the wharf quay at the Port of Dakar was carried out using the Gyropress method with high precision and minimal impact on the wharf and port operations. It was important not to use a method that would further damage the limestone marl layer which is already fractured. This project being a JICA ODA grant, the change of methodology after the preparatory survey stage is a rare case. However, after considering many factors, the initial design was changed from gravity quay type to quay on piles type, thus, the Gyropress method was selected over the All Casing method. That showed the effectiveness of the Gyropress method for a difficult construction site. During all construction periods, the port operation was able to proceed without any major changes.

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