

Case-history

Steel Tubular Pile Cofferdam Foundations in Bangladesh

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1. Introduction

The Japanese ODA loan project, named the Kanchpur, Meghna and Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project, was undertaken in Bangladesh. This is the biggest ODA project ever, in Bangladesh, which aims at shortening travel times and increasing the freight capacity of Dhaka-Chittagong National Highway No.1 (NH-1). The project involves the rehabilitation and retrofitting of existing bridges and the construction of 2nd bridges alongside the existing bridges. In order to construct high quality infrastructures, Japanese technologies, such as Tubular Pile Cofferdam Foundations and narrow box steel girder type monolithic with Steel Concrete Composite Slab, were adopted on the project. In this report, the Tubular Pile Cofferdam Foundation and the selected construction method, “The Press-in Method”, are highlighted.



Fig 1 Project Location Map

2. Background of the Project

In Bangladesh, the economic growth was steady in the 2000's, maintaining a GDP growth rate of around 6% per annum. The amount of freight has increased at a rate of 6-7% in recent years at the same pace as the GDP growth.

Profile of Bangladesh

Population: 159M (the 8th largest in the world), Land area: 147,000 square kilometers, GDP: 227.9B US dollars.

Reasons for Project Demand

1) Substantial shortage of capacity for present and future traffic demand

The traffic capacity on the main roads connecting the major cities and metropolitan areas in Dhaka cannot keep up with the year-after-year increase of traffic volume, and eliminating bottlenecks on distribution routes is the major priority.

The NH-1, namely the Dhaka-Chittagong Highway, is the lifeline for the economy of Bangladesh. The capacity, Annual Average Daily Traffic (AADT), of the NH-1 is 25,000 vehicles. The NH-1 will be a part of the Asian Highway that connects

with neighboring countries. Along this highway, the existing Kanchpur, Meghna and Gumti Bridges are major structures which cross the Lakhya, Meghna and Gumti Rivers. The Government of Bangladesh has planned to widen the NH-1 into 4-lanes in order to increase traffic capacity and remove traffic bottlenecks in the earthwork section. However, these existing bridges remain critical bottlenecks hindering the widening of the NH-1.

In 2012, the Average Daily Traffic (ADT) of the NH-1 was 75,000PCU at the existing Kanchpur Bridge and 65,000CPU at the existing Meghna/Gumti Bridges. The amount of ADT has already exceeded its traffic volume capacity by more than 10% at the Kanchpur Bridge and 60% at the Meghna/Gumti Bridges. In addition, due to the increase traffic trend, the forecast traffic volume in 2025 will exceed capacity by 100% at the Kanchpur Bridge and 200% at the Meghna/Gumti Bridges. It is obvious that the existing bridges will fail to cope with the increase traffic volume of the NH-1. This will cause serious traffic congestion. Therefore, the construction of new 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges became an essential issue.

2) Introduction of new seismic design standards

In addition, the “Bangladesh National Building Code (BNBC)” was implemented in 1993, and Bangladesh earthquake standards were raised in 2006, which mean existing bridges no longer meet the earthquake standards. The existing bridges were designed in accordance with the seismic coefficient of 0.05. The revision of the BNBC (2006) substantially increased the coefficient to 0.15. Therefore, the restoration and reinforcement of the bridges have undoubtedly become a pressing issue.

Thus, in June 2011, the Government of Bangladesh requested JICA to undertake a study for the repair and reinforcement of the existing Kanchpur, Meghna and Gumti Bridges on the NH-1, and the construction of the 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges. The Kanchpur, Meghna and Gumti Bridges are important bridges, located on the NH-1 connecting Dhaka and Chittagong which is the key corridor that supports the economy.

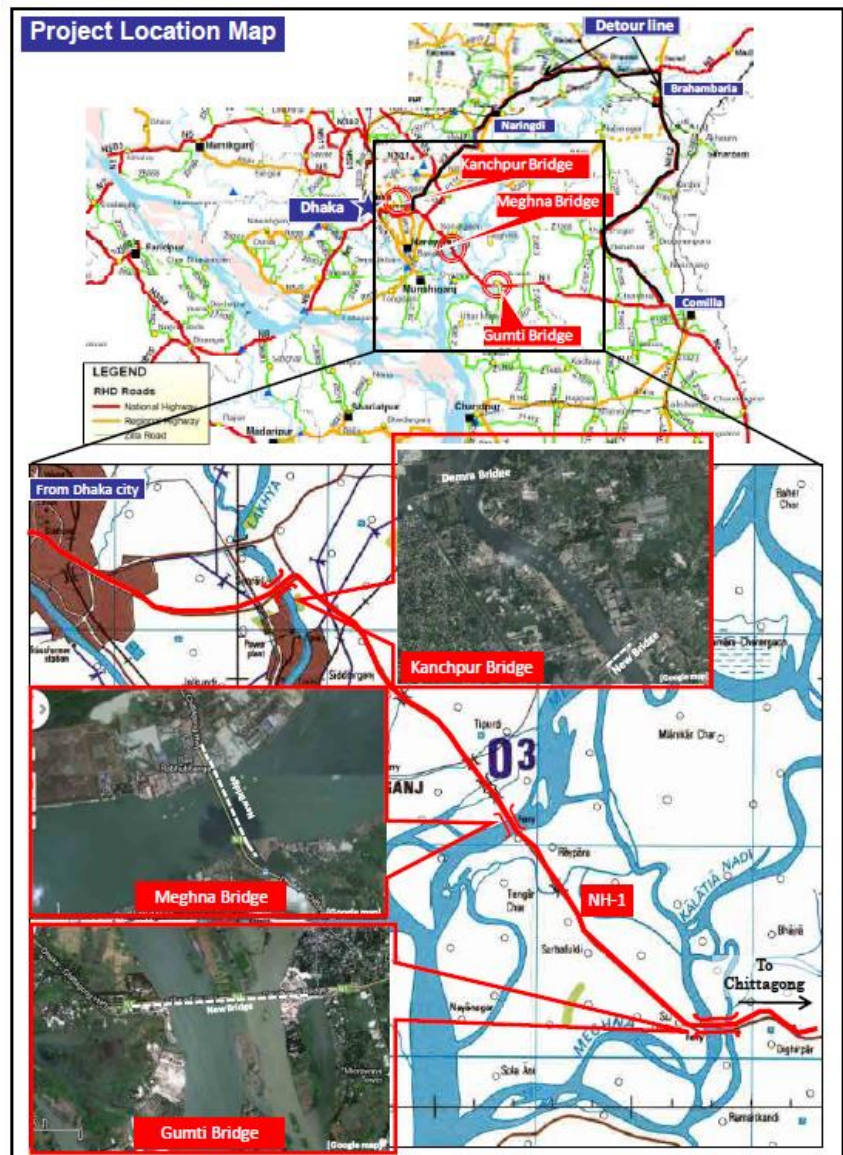


Fig 2 The NH-1 and Existing Bridges

3. Project Objectives

In accordance with the context of the preceding section, it was concluded that the three existing bridges needed to be retrofitted and three new 2nd bridges needed to be constructed to meet the increase traffic demand of the NH-1. As such, the overall objective of this project consists of the rehabilitation of the three existing bridges and the construction of three new 2nd bridges.

- 1) Construction of new 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges to facilitate the increase traffic demand

Table 1 shows vehicle traffic forecasts and required additional lanes for the bridges. The traffic volume of the Kanchpur Bridge was 76,732 cars per day in 2012 and will be 123,301 in 2021 and 192,687 in 2030. This sharp increase requires an additional 4 lanes to the current 4 lanes. The traffic volume of the Meghna and Gumti Bridges was 65,008 cars per day in 2012 and will be 105,374 in 2021 and 165,168 in 2030. These 2 bridges also require an additional 4 lanes to the current 2 lanes. Therefore, the new 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges are all designed as 4-lane bridges.

Bridge	Vehicle Traffic (cars / day)			Number of Lanes	
	2012	2021	2030	Current	Add
Kanchpur	76,732	123,301	192,687	4	+4
Meghna/Gumti	65,008	105,374	165,168	2	+4

Table 1. Traffic Demand and Traffic Forecast

Taking into consideration the above project objectives, a survey work was carried out in order to appraise the Japanese ODA loan that will cover the total project cost, the project implementation framework and the environmental and social aspects of the construction.

2) Retrofitting of the existing bridges

The three existing bridges are damaged due to the use of much overloaded trucks and the continual scouring on the bridge piers over time. At the same time, they were designed in accordance with the outdated seismic design standard and need to be upgraded using the new seismic design standard of BNBC (2006). The extent of rehabilitation of the existing bridges depends on the inspection and assessment of their above condition and retrofitting them to secure their reliability as bridge structures.

4. Outline of the Project

- 1) Project Name: The Kanchpur, Meghna and Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project
- 2) Execution Agency: RHD (Bangladesh Roads and Highways Department) under Ministry of Communication
- 3) Main Contractor: Obayashi-Shimizu-JFE Engineering -IHI Infrastructure Joint Venture
- 4) Construction Budget: International Yen Loan of JPY29 Billion
- 5) Project Duration: 7 years and 8 months from December 2015
- 6) Duration of Piling Works: February to October 2017

5. Type of Foundation

In order to satisfy the design requirements, a “Steel Tubular Pile Cofferdam Foundation” was adopted on the project. A steel tubular pile cofferdam foundation comprises steel tubular piles with interlocks, which form an enclosed area. The wall acts as a cofferdam during the construction of the substructure and each interlock is initially emptied and filled with grout to provide necessary water tightness for the cofferdam. After dewatering and excavation to the required depth, the tubular piles are joined to the base RC slab as a permanent substructure. The tubular piles are then cut off at the top of the RC slab to allow water flow around the foundation.

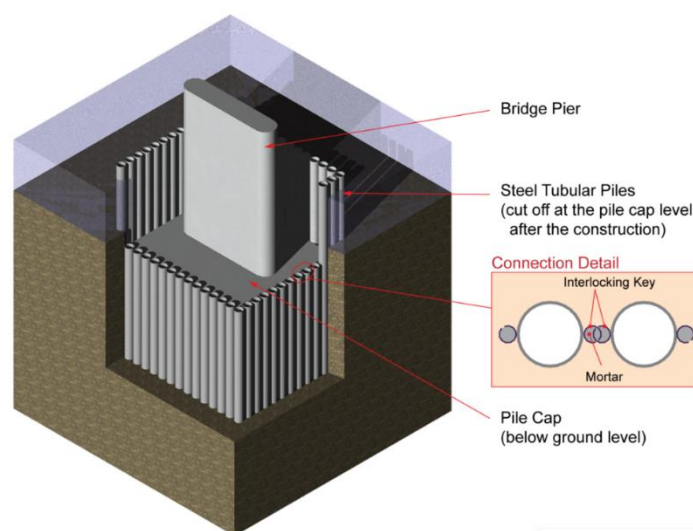


Fig 3 Overview of Steel Tubular Pile Cofferdam Foundation

The steel tubular pile cofferdam foundation originated in Japan and can achieve substantial cost savings for bridge foundations that need to be constructed underwater or under soft ground conditions. The main advantage of this foundation system is that it acts as both a temporary cofferdam and a permanent foundation, leading to a reduction in construction costs and time simultaneously. Also, this system is very effective as it provides anti-seismic reinforcement and scour protection for bridge piers.

Fig 4 shows the comparison of a steel tubular pile cofferdam foundation and a traditional RC pile foundation. New bridge

piers are constructed adjacent to existing piers, enclosed with a shared cofferdam and joined together.

	Steel Tubular Pile Cofferdam Foundation	Plan B: RC pile
Image		
Cofferdam	Not required	SP
Foundation size	Small	Large
Cost	1.00	1.92
Evaluation	⊙	

Fig 4 Comparison of Steel Tubular Pile Cofferdam Foundation and RC Pile Foundation

RC pile foundations require a temporary sheet pile cofferdam to provide a dry working space, for a piling machine to carry out RC pile installation in a water environment. Also, the footprint of the RC pile foundation is much larger than that of the steel tubular pile cofferdam foundation. This results in nearly twice as much construction cost and time using the RC pile foundation, compared to the steel tubular pile cofferdam foundation, on this particular project.

6. Overview of the Foundation

1) Kanchpur Bridge. (Fig 5)

Bridge Length: 400m with 6 piers.

Steel Tubular Piles: 352 no. 1,000mm diameter tubular piles L=28m - 41.5m



Existing Bridge



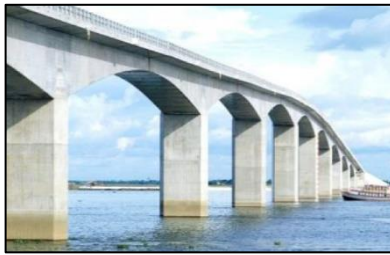
Completion Image

Fig 5 Kanchpur Bridge

2) Meghna Bridge. (Fig 6)

Bridge Length: 930m with 11 piers.

Steel Tubular Piles: 765 no. 1,000mm diameter tubular piles L= 45.5m - 56m



Existing Bridge



Completion Image

Fig 6 Meghna Bridge

3) Gumti Bridge (Fig 7)

Bridge Length: 1,410m with 16 piers.

Steel Tubular Piles: 510 no. 1,000mm diameter tubular piles L=41.5m - 55m (6 piers only)



Existing Bridge



Completion Image

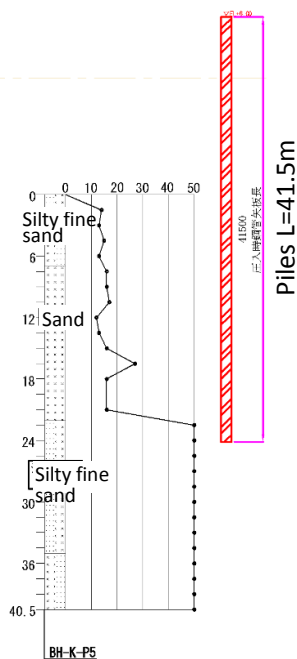
Fig 7 Gumti Bridge

7. Ground Conditions and Pile Installation Method

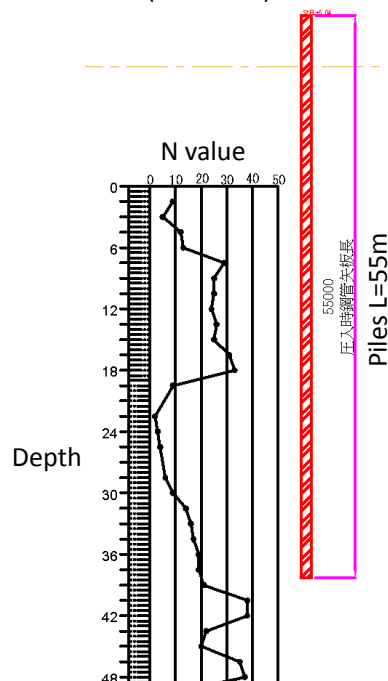
The typical ground condition on this project is layered soil, comprised of clay, silt and sand as shown in Fig 8. As the maximum SPT N value exceeds 30 or 50, the Press-in with water jetting mode was utilized.

1) Ground Conditions

Kanchpur Bridge
(Nmax>50)



Meghna Bridge
(Nmax<50)



Gumti Bridge
(Nmax>50)

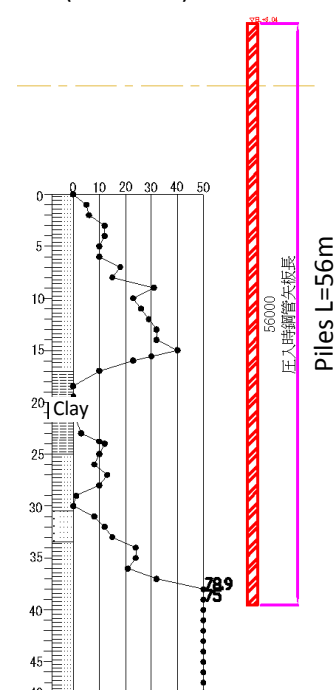


Fig 8 Typical Borehole Logs

2) Pile Installation Mode

When the ground is medium dense/stiff or denser/stiffer, pile installation by the standard Press-in Method can be difficult due to the increase of installation resistance. The water jetting mode is suitable for dense or stiff ground conditions with STP N value of up to about 50 or undrained compressive strength C_u of up to about 150kPa. The water jetting can minimize the tendency of pressure bulbs and pile plugs, which are created at the pile toe during press in operations. At the same time, the water jetting can temporarily reduce skin friction during pile installation. The operation of Press-in with Water Jetting comprises the Silent Piler, the Piler Jet Reel atop the Silent Piler, the Power Unit of the Silent Piler and the Water Jet Unit, as shown in Fig 9.

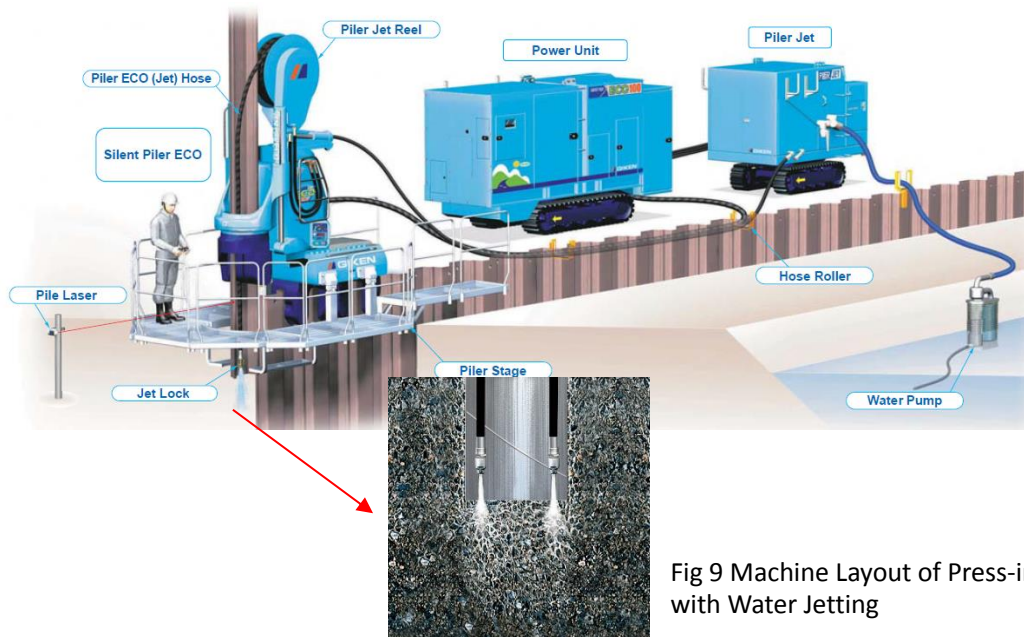
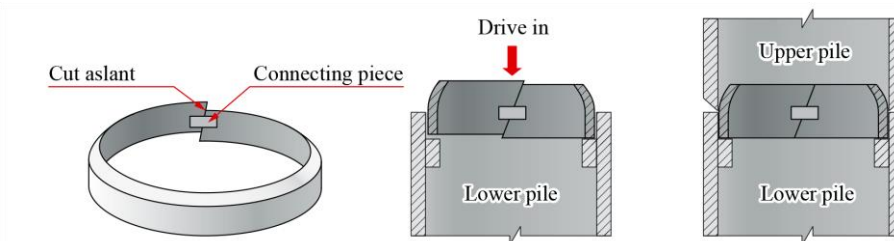


Fig 9 Machine Layout of Press-in with Water Jetting

3) Overhead Clearance Method

On such projects, the steel tubular cofferdam foundations are installed within a low headroom under the existing bridges. Therefore, during pile installation work, after the bottom pile is installed, the next pile is spliced atop. This process is repeated until the full length of pile is installed. On these projects, the traditional circle welding method was utilized to spliced piles. Before the steel tubular piles were delivered, they were cut into designated lengths in accordance with the available overhead clearance under the bridges. The bottom of each upper spliced pile was beveled to allow full penetration butt welding with multiple passes. At the splice joint inside each pile, a backing strip is tightly fitted prior to welding. This provides support for a fully penetrated root pass. The circle welding is carried out in the vertical position and care should be taken to prevent the overflow of welded material. A temporary copper strip is attached to the top of the lower pile, to help to prevent this overflow. Some of the details of the execution of the projects are given in Fig 10 to Fig 13.

Details of Backing Strip



Details of Copper Strip

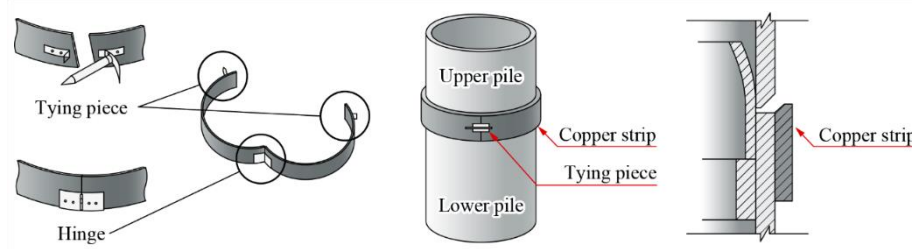


Fig 10 Preparation Details for Circle Welding

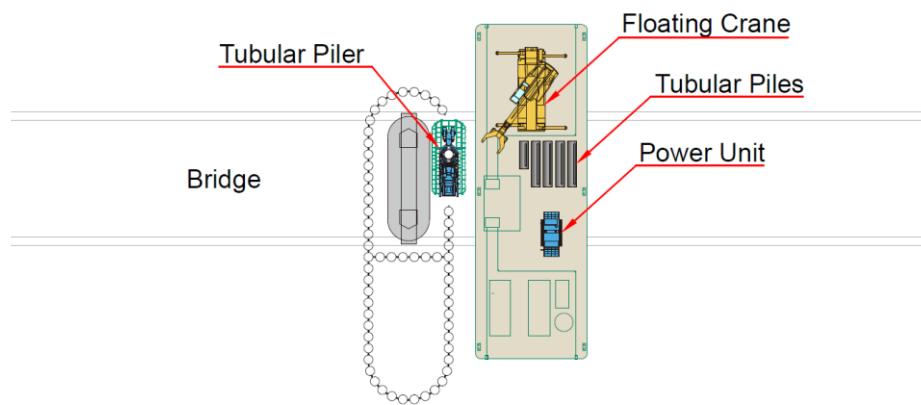


Fig 11 Machine Layout (Plan)

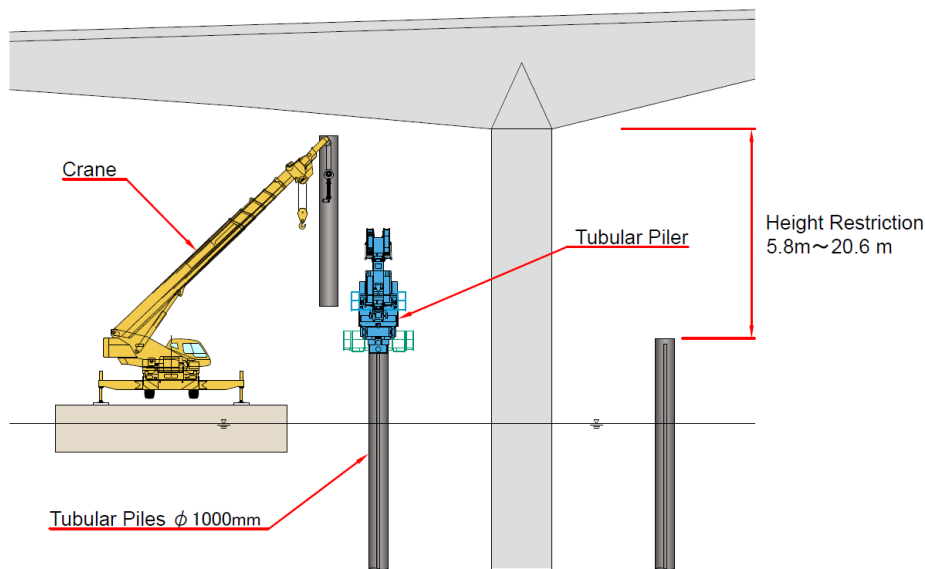


Fig 12 Machine Layout (Front View)

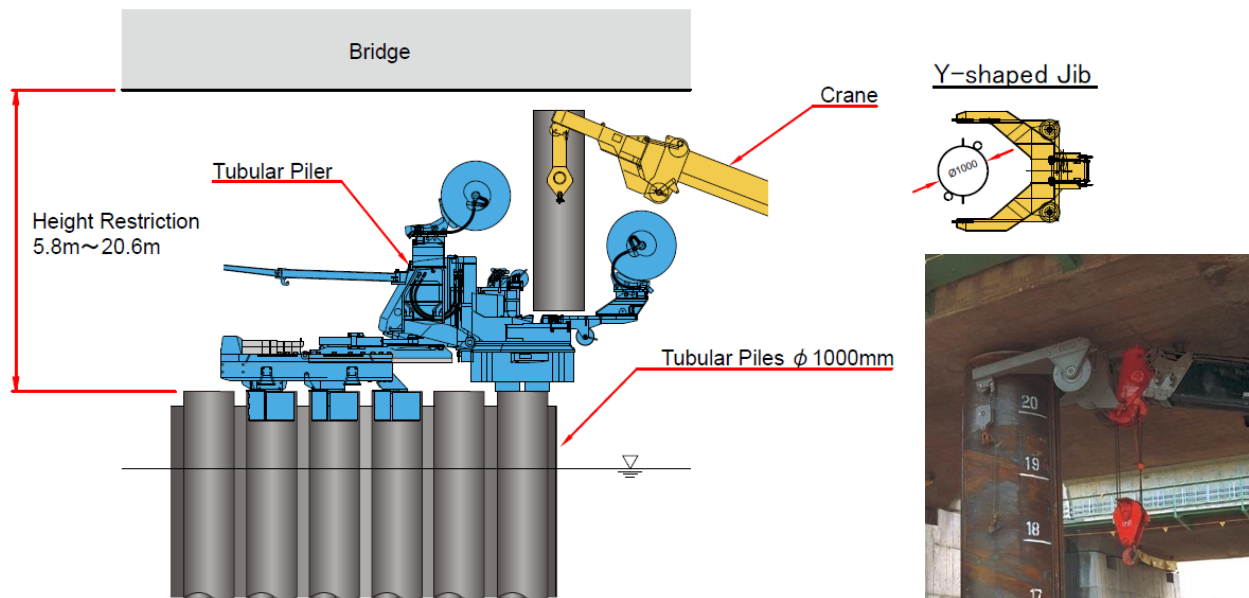




Fig 13 Machine Layout (Side View)

8. Conclusion

In urban construction scenarios, working conditions are much more complicated when upgrading/retrofitting infrastructures as the construction often needs to be carried out adjacent to existing everyday activities. Also, space limitation as a result of existing infrastructures is especially hindering on foundation construction, as it usually restricts implementation of the works.

Steel tubular pile cofferdam foundations are effectively used not only for new bridge foundations, but also these types of bridge foundation retrofitting works. This simple and effective solution enables bridge foundations to be constructed within a minimal period of construction time. With the Press-in Method, steel tubular pile cofferdam foundations can be constructed under extremely restricted working conditions, such as overhead restrictions, restricted working platforms or hard ground conditions without impacting on the surrounding environment.

In the service phase, functional adaptations of infrastructures may be required due to a higher demand of functional requirements, shorter structural lifetimes than planned or the necessity of further usage of the same structure at the end of its planned life. To meet the functional adaptations, traditional structures with the “Scrap & Build” design concept ultimately need high renovation construction and demolition costs. However, with the above combination, structures can more effectively and efficiently satisfy the stipulated functional adaptation. Therefore, the total investment costs i.e. construction, operational, maintenance, renovation construction and demolition costs can meet the optimum cost/quality balance.

REFERENCES

- [1] Japan International Cooperation Agency: Website <https://www.jica.go.jp/english/index.html>
- [2] Preparatory Survey for Dhaka-Chittagong National Highway No.1 Bridge Construction and Rehabilitation Project Final Report 55