CONSTRUCTION OF PASSENGER JETTY AT MANDWA USING END-ON METHOD

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ABSTRACT: Jetties are piled projections built out from shore to deep water. In the present paper, a case study on construction of 353m long passenger jetty at Mandwa, Alibaug, using end-on method is presented. The passenger jetty was constructed using bored cast-in-situ piling using movable steel piling gantry which moves in forward direction over the previously completed pile rows. A total of 67 piles of 750 mm diameter were cast for approach work and 34 piles of 900 mm diameter were cast for the berthing structure. This novel end-on method is preferred in marine works as it reduces the cycle time for piling in case of work of repetitive nature.

INTRODUCTION
Jetties are the structures in the form of piled projections, built out from shore to deep water. They may be constructed either for a navigable river or in the sea. In rivers, the jetties divert the current away from the river bank and thus, the scouring action is prevented. As the current is diverted to deep water, the navigation is also controlled. In the sea, the jetties are provided at places where harbour entrance is affected by littoral drift or the sea is shallow for a long distance. Thus, they extend from the shore to the deep sea to receive the ships.

In the limiting sense, a jetty is defined as a narrow structure projecting from the shore into water with berths on one or both sides and sometimes at the end also. Jetties are exposed to severe wave action. Depending upon the natural conditions and features of the entrance channel, the jetties should be constructed and they may take various forms such as single curved jetty, converging jetty, diverging jetty, etc. Berthing facilities like wharfs and jetties are provided at ports for the vessels, to facilitate the loading/ unloading of goods and provision of other services. These berths are supported on piles and generally, the superstructure in the form of beam and slab system is constructed using precast elements. Various types of piling techniques such as precast piles, bored/driven cast-in-situ piles are employed in construction of substructures for jetties, of which bored cast-in-situ method being commonly adopted. Piling has been the economic form of construction for cargo jetties, berthing structures, and pipe trestles for oil tankers [1]. Driven and cast-in place piles with sacrificial liners are used for sites over water for jetties, piers, etc. [2].

PILE FOUNDATIONS
Pile foundations are long slender structural members which can carry vertical, horizontal or inclined loads and transfer the load of superstructure to the bearing strata. The main component of the pile foundations are the pile shaft and pile caps. Piles are long and slender remember which transfer the load to the deeper soil or rocks by friction or by bearing the main types of materials used for piles are wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to the pile caps. Depending on types or materials, soil and load transmitting characteristic piles are classified accordingly.

Piles are used where adequate bearing capacity is not available at shallow depths. Though piles get support from both end bearing as well as friction, piles are broadly classified as end bearing, friction piles, settlement reducing piles, tension piles, laterally loaded piles, under-reamed piles and micropiles. End bearing piles derive support from bottom while friction piles resist load skin friction. Settlement reducing piles are used below the central portion of a raft foundation to reduce the differential settlements. In the case of tall structures such as chimneys, transmission towers, etc. and also in the case of jetties, where large overturning moments and resulting uplift forces are to be supported, piles are designed as tension piles. Laterally loaded piles are designed in cases of wharves and jetties carrying the impact forces of berthing ships, piled foundations for bridge piers, trestles of overhead cranes, tall chimneys and retaining walls, where the horizontal force is dominant. Under-reamed piles are the piles with under-reams or bulbs. These are used in the case of foundations in expansive soils. Micropiles are small diameter piles with diameters ranging from 15cm to 30cm and are generally used for lighter loads and also where it becomes difficult to transport the normal piling frames and equipments for pile construction works due to limited space.

Based on the method of installation, piles are classified as displacement piles when the soil is displaced radially as well as vertically when the pile shaft is driven into the ground and non-displacement piles when soil is removed and the resulting hole filled with concrete or a precast concrete pile is lowered into the hole and grouted in. Pile foundations are constructed either by driving the piles in to the ground by drop hammers, diesel hammers, vibratory method or by boring and filling the void by concrete and steel. Bored piles are constructed by drilling the bore using methods such as
In the marine environment, for berthing structures/jetties, piles are lowered to the required position under its self-position. After shifting and guide fixing, mild steel (MS) position on main girder of gantry, it is shifted to the required concreted pile gains sufficient strength. After marking the cast previously. Shifting of gantry is done one the freshly and depths. The piling gantry rests on the pile row which is economical and ideally suited for piles with large diameters and various advantages like it is comparatively much more economical and ideally suited for piles with large diameters and depths. The piling gantry rests on the pile row which is cast previously. Shifting of gantry is done one the freshly concreted pile gains sufficient strength. After marking the position on main girder of gantry, it is shifted to the required position. After shifting and guide fixing, mild steel (MS) liners are lowered to the required position under its self weight. The each liner units are connected at the bottom as per the length of pile required. After reaching the required location on sea bed, the liners are driven in to the bearing strata by using the driving hammer. Boring is done using bailer, a steel vertical cylinder and a cross-chisel, a cutting tool to remove the soil within the liner and a hole is formed to cast the pile. Boring is done till the founding level is reached. Bore depth is checked by doing sounding with chain at regular intervals during the process of boring and after completion of boring. The bore hole is thoroughly cleaned and the reinforcement cage is lifted from the pontoon and lowered into the hole. The main bars of the cage are lapped and helical reinforcement is fitted in position. Tremmie is lowered into the cage from the piling tower up to 300mm above the bottom of the borehole. After all the tremmie pipes are lowered, flushing is carried out to clean the hole before concreting. The concrete with high slump is prepared in automatic weigh batching plant and transported to the site in transit mixture, and is than pumped into bore. As the concreting progresses, the tremmie pipe is slowly lifted and topmost pipes are detached and concreting is resumed. It is continued till the bore is filled by concrete.

The end-on method is practiced economically in any weather condition. However, it suffers from the limitation that it cannot be used economically where the piling bents are driven at wide centre to centre distance since the design of cantilevering frame becomes heavy and uneconomical for greater pile spacing. Pile driving from temporary falsework may be economical where piles are driven closely and in shallow waters near the shore. The other method of piling in water consists of erecting pile frame on one end of rectangular steel platform. For the light pile bents, ordinary barges can be used. In the case of floating pontoons, pontoons are provided with four powered winches for warping them into the position. For stability of vessel and to counteract the weight of frame, pontoon cells are filled with water. For driving piles, single acting hydraulic or diesel hammers are preferred to the drop hammers since blows can be controlled with greater accuracy and less damage to the pile.

**END-ON METHOD**

The end-on piling method is a popular method of piling where works of repetitive nature are to be executed. In this method, piling gantries are used and the gantry moves in forward direction on completion of a row of piles and the next row of piles is constructed and the work continues. This method is popularly known as end-on method since the piling is done by deploying equipment on the gantry along the edge, and the gantry is moved in forward direction to construct the next rows of piles. Figure 1 shows the piling gantry used in the end-on method.

A piling gantry is made up of steel considering the actual site conditions, loading and structure of jetty. Gantry functions as a platform for pilling towers, winches, bailers, chisels, hammers, tremmie pipes, hoppers etc. required for piling. Generally, bored cast in-situ piles are preferred due to various advantages. The bored cast in-situ piling method offers various advantages like it is comparatively much more economical and ideally suited for piles with large diameters and depths. The piling gantry rests on the pile row which is cast previously. Shifting of gantry is done one the freshly concreted pile gains sufficient strength. After marking the position on main girder of gantry, it is shifted to the required position. After shifting and guide fixing, mild steel (MS) liners are lowered to the required position under its self

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**Fig. 1.** The piling gantry used in end-on piling method.
movement is prevented by tightening the brakes of the
wheels.

ADVANTAGES OF END-ON METHOD
In the case of construction of marine structures, time of
completion of project can get delayed due to many
unforeseen reasons. One important factor that controls the
project duration is cycle time which is defined as the time
required to complete the repetitive sequence of operations.
For marine structures, cycle time may be higher if events are
not planned well. For instance, in the case of piling, cycle
time refers to completion of the construction of a bored cast
in-situ pile, from liner lowering to concreting. Proper initial
survey and anticipation of site problems and planning in
advance can reduce the cycle time. Also, the cycle time can
be reduced by using innovative techniques such as end-on
method.

The sequence of activities in piling work include marking and
guide fixing, lowering and pitching of liners, boring and
cleaning of hole, reinforcement cage lowering, tremmie
lowering, flushing, concreting and gantry shifting. The cycle
time used for casting of one pile is generally 10-12 days, but
by using proper planning, latest technologies, this cycle time
can be reduced to half by proper planning. This is the main
advantage of end-on method. This method is thus the most
efficient and economical since it consumes less time for
piling resulting in overall economy.

PRESENT STUDY
In the present study, the end-on method adopted for
construction of the new passenger jetty at Mandwa,
Alibaug in Mumbai by Maharashtra Maritime Board is
presented. The construction work was executed by M/s.
Indiana Build Infrastructure Private Limited is presented.
The work of main berth and approach jetty comprised of
bored R.C.C. piles for the sub-structure and grid of
precast/cast-in-situ concrete pile caps, beams, fender walls
and deck slab, etc. in the superstructure

The present work of the construction of new passenger jetty
at Mandwa, Alibaug involves the total jetty length of 353m
with the approach length of 300m and the berthing length of
53m. Total 101 piles were cast for the project, of which 67
piles were of 750mm dia were used for approach jetty and
remaining 34 piles were of 900 mm dia were used for
berthing portion. All the piles were bored cast in-situ type
with M30 grade of concrete. Fe415-TMT grade bars were
used as reinforcement amounting to 145 MT were used for
piling work. Piles were provided with 5mm thick sacrificial
MS liner. Superstructure consists of cast-in-situ beams,
precast beams and slabs. Paving was done with paver blocks
on deck slab for total area of 4000 sq. m. area. The railings
were laid for over length of 762 metres. A total of 9 bollards
were provided. The piling work was completed by using 4
YDA Ruston engine with 5 Ton winch machine mounted on
movable gantry. Pool integrity tests and pile dynamic tests
were carried out on the piles. Figure 2 shows the existing and
the new passenger jetty constructed at Mandwa, Alibaug.

METHODOLOGY USED
Bored cast-in-situ piles of 750mm dia and 900mm dia were
constructed at the site. The piling was carried out by using
gantry or/and using platforms as per the existing site
conditions. A piling gantry was fabricated and erected to
facilitate the boring and concreting of piles for approach as
well as main jetty and handling other components. Piling
gantry was erected mainly at two locations i.e. one near the
shore line land and the other at the existing extended jetty.
The top of the gantry was maintained at a reasonable
level above MSL so that the continuity of the work
was not disrupted time & again. On the above gantry,
two piling rigs were installed to carry out the boring of
piles in a row. Sacrificial mild steel liners of 5mm
thickness were lowered up to top of soft rock. The moving
piling gantry used at Mandwa site is shown in Fig. 3.

Fig. 2 Existing and the new passenger jetty at Mandwa,
Alibaug.

Fig. 3 Moving pile gantry used at Mandwa, Alibaug

On the completion of boring of piles, the pile
concreting was done by tremmie method, with the help of
weigh batcher - concrete mixers already placed on the
travelling gantry. The existing jetty was used without
affecting/disturbing the movement of passengers. After
completing the piling operations on both the piles in each
row, the gantry was shifted on to the next destination after
24 hours after completion of the tremmie concreting and
bracings as required. When the advancement of gantry
was taking place at pace of one or two piles as per the required centre to centre distance, the work of placing of cast-in-situ beams, slab was taken up simultaneously over the permanent piles. On initial setting of the concrete in the piles, the launching operations of the moving gantry was commenced for preparing the position for driving the subsequent piles as per the programme and the boring operation of next piles was commenced thereafter. Figure 4 shows the completed piles using end-on method.

In the present case, after completing the piling operations on 2 - 3 piles in each row, the gantry was shifted to the next destination. The existing mooring dolphin with connected walkways and its sub-structure was also used to expedite the work progress without affecting/disturbing the traffic. Pre-casting of RCC superstructure elements was carried out at the nearby casting yard and also at the site proper as per site requirements.

When the advancement of gantry was taking place, the work of superstructure was carried out as “end-on” system i.e. progressing from span to span and launching and placing in position the precast elements by using gantry/portal frame or crane from the previously cast spans. The portal frame/gantry was supported on the piles by temporary brackets/piles to handle and place precast members in proper position. Necessary bracings were required to be provided to support the gantry. Mobile cranes can also be used for handling and placing of precast members. Using of precast elements in marine environment provides advantages of better quality control on concrete quality as precasting is done in casting yard and no need to provide shuttering/staging during the concreting in place. Necessary required size holes are provided in precast units for handling of the precast elements before its final position and for miscellaneous works regarding fixing shuttering, etc. These holes are to be filled back with rich concrete/mortar after its final placement. The other accessories like ‘V’ type rubber fenders, M S ladders, Mooring rings, M S Bollards and other miscellaneous items were also provided as required. Figure 5 shows the completed piles and precast main beams for the passenger jetty.

![Fig. 4 Piles constructed using end-on method at Mandwa, Alibaug.](image_url)

**CONCLUSIONS**

The end-on method is a popular method of piling useful when works of repetitive nature are to be executed. Bored cast-in-situ piling can be advantageously used along with end-on method for construction of marine structures like jetties since it is economical for large diameter and long piles. In the marine environment, for berthing structures/jetties, piles are to be driven either by end-on method or by using floating or jack-up barge. End-on method of piling offers the advantage of reduced cycle time, thus saving the total project duration and project cost. Cycle time can be reduced from 12 to 6 days by proper planning and execution of piling works. This method has limitation that the spacing of piles has to be restricted due to limitations on the ability of cantilevering girders carrying the weight of piling frame, hammer and suspended pile.

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**REFERENCES**