Special Considerations in Marine Pile Design and Construction

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ABSTRACT: By the term marine pile, it is commonly meant the piles used as a structural part of jetties, wharves, dolphins and other such near shore and off shore structures. Fundamentally all these piles are long slender members and subjected to massive horizontal forces. These piles have typical construction and design requirements which make them a different foundation arrangement when compared to their use as land piles. In design, these piles are generally subjected to large magnitude of bending moment along with axial force. This leads to special considerations like heavily reinforced section, large pile diameter etc. Aggressive condition of saline weather calls for extraordinary consideration of design as well as construction. In construction it is again an unusual treatment due to lack of accessibility and stable working area. Many methods like fixed platform, floating arrangements, cantilever platform, jack up barge etc. are the options available to tackle such conditions. In this paper, the author has highlighted such special requirements and also discussed the merits and demerits of the various materials used in pile construction like RCC, steel and prestressed concrete. Shortcomings of the use of construction practices of present day bored pile construction have been discussed. Provisions of various codes of practices have also been briefly highlighted.

1. INTRODUCTION

Every structure has its own requirement and specialty. Marine structures like berths, jetties, wharves, mooring and breasting dolphins along with other structures like offshore drilling platform, single point mooring systems are also designed and constructed with some specific considerations. Most importantly, all these structures have two particular aspects. They are subjected to large amount of horizontal forces and often the sub-structure part of these structures consists of long free standing length of pile. Large horizontal forces generally arise from wave, current, seismic, wind and sometimes earth and water pressures. These forces and the free standing cantilever length cause high order of moment and shear forces in the members. Operational forces like mooring and berthing forces from vessels are horizontal force in nature and for some of the structures; these are of very high order. Piles and sheet pile or diaphragm walls are to take care of these forces. In some cases gravity structures are constructed against these forces and by way of their own weight they resist overturning or sliding. Piles and diaphragm walls are the two structural elements that extensively form the part of above marine structures. Large diameter bored cast in situ piles, rectangular and ‘Tee’ shape diaphragm wall panels of diaphragm walls can resist these forces with their own structural rigidity and sectional modules. Steel sheet pile and steel piles, though not very popular in India, have their own advantages like flexibility. However, their criticality against corrosion and above all, their comparatively higher cost have made them less popular in India.

Construction of marine structures is also a critical issue. In absence of firm supporting ground condition, some special techniques require to be adopted. These support arrangement can be grouped in 3 sections viz: (1) structures erected on the already constructed structure (refer Fig. 1); (2) Floating arrangement like Barges etc. and (3) Structures supported on long spuds resting on sea or river bed (refer Fig. 2). All these arrangements and methodology of work call for specialized contractors’ involvement.
The other most important part of marine structure is the requirements arising from durability point of view. Under the severe marine environment with splashing of water, salinity coupled with difficult working condition of construction, many of the structures are vulnerable from point of view of long term durability. Provision of extra cover to rebar, control on crack width and/or limiting the stress level of reinforcement steel are essential requirements for Reinforced Concrete Structure. In case of steel (steel pile or sheet pile) extra thickness of material as corrosion allowance along with protective paint coating and cathodic protection are generally adopted.

2. DESIGN ASPECT OF MARINE PILES

RCC marine piles are essentially long cantilever slender piles embedded in soil or rock. The effective fixity is developed at some depth below the dredge level or sea bottom level. In one school of thought, the piles are considered as fixed end cantilever members and the depth of fixity is calculated as per equivalent length producing equal deflection. Provisions of Indian Standard code of Practice of Piles (IS 2911) are generally followed. However, the alternate method is using modulus of sub-grade reaction and applying spring support to the pile member of the jetty or wharf structure. In both the cases the frame structure in 2D or 3D model is analyzed generally using software analysis programme. The vertical capacity of pile is designed as per static formula of soil capacity. Structural design is thus done based on the shear and moment forces. It may be noted that in most cases the reinforcement percentage is governed by serviceability criteria of crack width, as per provision of IS or BS codes. Generally, piles are heavily reinforced. In case of steel piles similar method is followed but obviously crack width consideration does not arise in design. Steel piles can take large deflections and especially for mooring and breasting dolphins piles it helps in design.

There is no Indian code of practice available for steel pile. Code of Practice is generally prepared for land based piles and because of the above discussed requirements of marine piles, the designers encounter difficulty in designing the sub-structure. It may be noted that European and American construction practice on Maritime structure earlier was not in favour of the use of RCC bored cast in situ piles which has been adapted subsequently due to development in mechanized construction technology of RCC bored piling in recent years like use of Rotary Piling Rigs, Bentonite stabilization system etc.

3. MERITS AND DEMERITS OF VARIOUS PILING MATERIALS

Generally, 3 types of piles are used in marine environment viz. RCC Bored Piles, Steel Piles, Presstressed Concrete Tubular Piles. All these piles have their own advantages and disadvantages and have become adaptable to a region or country depending on various factors.

3.1 RCC Bored Piles

This type of pile is very popular in India and some other countries. After the development of very large diameter bored piles during seventies in India, this pile found its place in marine structure like jetties etc. owing to its structural stiffness. These piles have the necessary sectional modules that are required against the large magnitude of bending moment which was not possible earlier with small diameter piles. However, these piles are vertical piles and racker bored pile is usually not possible to construct. This limits its design consideration but which is possible with steel or prestressed concrete driven piles.

From construction point of view there are some difficulties. Bearing capacity at tip is often questionable in bored pile unless the flushing system of bore hole and bentonite management system are proper. Against large axial load this is a major disadvantage. In fact British Code of Practices for maritime structure was not in favour of bored cast in situ piles for marine structures without sufficient precautions. But with the advancement of bored pile technology, this concept has been nullified. In another aspect, the modern day’s use of boring technology using Rotary Piling Rigs etc. has not also been adopted in general for marine projects in India and older methods of boring are still followed.

3.2 Steel Piles

Steel piles are very popular in Europe and America. Availability of heavy capacity driving hammer in one hand and non-availability of large number of workforce on the other hand made this pile more popular than bored piles in those countries. Racker steel piles can also be constructed. Quality control is more easily achievable in steel piles.

The steel piles are comparatively more costly. Further, many additional requirements are also associated with steel piles to
prevent their deterioration due to corrosion. Generally a corrosion allowance in the form of sacrificial thickness of pile wall is provided. In addition to it, a protective coating of paint and also cathodic protection system are considered. In spite of all these restrictions, steel piles have been used in some of the Indian coastal projects because of requirement of faster method of construction, racker in piles etc.

3.3 Prestressed Concrete Piles

Though not very popular in India, it has its own advantages and disadvantages and used in few Indian projects. This piles being prefabricated, the method of installation time is faster, quality control is more achievable, no difficulty due to bottom cleaning and raking of piles is possible. These piles are cheaper than steel piles and no separate painting or cathodic protection or corrosion allowance is required. However, these piles have shown some distress in some of the projects particularly under severed seismic load, there is some doubt about its performance. If not properly designed against a particular heavy hammer the internal stresses some time create structural damage while driving. These piles have a great opportunity in future when some of their deficiencies are overcome.

4. SHORTCOMING OF PRESENT DAY PRACTICES OF BORED PILE CONSTRUCTION FOR MARINE STRUCTURE

Due to constructional restraints in marine environment, use of heavy machinery which have come up in recent past for bored pile construction are not very suitable. Piles of marine structure are generally carried out from a cantilever or fixed structural platform having limited access from shore or using jack up barge, floating barge etc. In all these cases weight of rotary boring rigs is difficult to accommodate. For this reason percussive tools are used for boring the holes using light weight rigs. Though it solves the problem of its supporting structure, the quality of hole is not as good as rotary rigs. This method of boring is slow and often bottom cleaning is practically not possible. All these inherent shortcomings of percussive boring may sometimes produce poor quality of shaft or end bearing if not properly checked at all construction stages. However, if proper technology is adopted and quality control measures are taken, past records show that present day practice can produce acceptable results.

5. DISCUSSIONS OF PROVISION OF INDIAN AND OTHER CODES OF PRACTICES FOR MARITIME STRUCTURE

The India marine codes of practices are under series of IS 4651 (various parts), IS 9527 (various parts) and British Codes of Practices are BS 6349 (various parts). In all these codes general design and construction requirements are covered but for pile foundation of these structures, pile codes like IS 2911 (various parts) or BS 8004 has been referred. However, these pile codes specially IS 2911 is primarily meant for land based piles. As a result, there are some clauses which require special consideration in the design. Being very large, slender and cantilever type of piles, the deflection of the structure is often at variance with normal land based piles though structurally they are safe. Load test in marine condition is always difficult. Moreover, the permissible load carrying capacity and load deflection criteria of IS 2911 (Part–IV) sometimes gives conflicting results. Presently, there is no code of practice available for steel and prestressed concrete piles. With all these serious drawbacks, it is necessary to incorporate suitable provision in the code of practice for piles.

REFERENCES

BS 6349 British Standard – Maritime Structures.
Tomlinson M.S., Pile Design and Construction Practices.