A kind of anchoring foundation with multi bucket embedded when penetrating into seabed

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Abstract. The construction of anchoring foundation in ocean engineering depends on construction equipment. Among them, bucket foundation is a convenient and fast construction tool for marine anchoring foundation. But at present, many kinds of anchoring foundations based on bucket foundation construction have their own limitations. In this paper, a new type of bucket foundation based on bucket foundation construction is proposed, which is composed of multiple buckets, after deployment in the seabed, each bucket is connected based on the anchoring hole, and the attitude of each bucket is not the same, which can maximize the friction with the seabed soil, thus improving the overall uplift capacity.

1. Introduction
In view of the special geological conditions of the seabed, a special foundation form of offshore platform bucket foundation (suction pile) has appeared since 1990. It is mostly an inverted large diameter steel bucket with an open bottom and a closed top. During the installation, the bucket body is partially inserted into the soil to form a closed space in the predetermined sea area by its own weight, and then the gas or liquid between the bucket body and the soil is extracted to form a pressure difference between the inside and outside of the bucket body, which is gradually pressed into the predetermined depth of the seabed to complete the installation[1–4].

Based on the characteristics that bucket foundation is more convenient to penetrate into the seabed at sea, engineers develop bucket foundation as a kind of construction tool for marine anchoring foundation[5–6]. Some countries have strong offshore engineering construction enterprises (such as SPT offshore company of the Netherlands), which can use bucket foundation to carry out all kinds of offshore engineering construction, and the degree of automation and intelligence is very high. Although China is a big maritime country and has a large area of sea, there is still a gap between China and foreign countries in the construction of ocean engineering by using bucket foundation.

At present, the anchoring foundations that can be used for construction mainly including embedded suction anchor and suction embedded plate anchor. But these anchoring foundations have their own limitations[7–8]. It can be seen that the configuration of suction embedded anchoring foundation based on bucket foundation needs to be innovatively designed to make it have larger pull-out bearing capacity and more convenient for construction.

2. Multi-bucket interbedded combined anchoring foundation
For this reason, this paper proposes a multi- barrels interbedded combined anchoring foundation during construction, including no less than two barrels. The barrel is a hollow barrel, the outer side of the barrel is provided with a mooring hole, the bottom of the barrel is provided with an inward protruding card
The barrel is divided into the innermost barrel and the non-innermost barrel according to the position relationship, in which the non-innermost barrel needs to be provided with bayonets so that the mooring holes on all the barrels embedded inside can extend out the outside of the barrel wall. During construction, each barrel is interbedded and stacked according to the diameter relationship of each barrel, so that the bottom of the inner barrel is pressed on the card slot of the adjacent outer barrel, and the mooring hole on the inner barrel extends out based on the bayonet on the outer barrel. The mooring holes of each barrel are connected with steel cables from inside to outside in order to make each barrel form a series shape, and mooring one end of the chain to the mooring hole of the innermost barrel. Then the bottom of the bucket foundation is embedded in the innermost barrel and pressed on the card slot of the innermost barrel, depending on the bucket foundation, the anchoring foundation is penetrated to the design depth of seabed, and then the bucket foundation is removed. Then the tension is applied to the anchor chain to make each barrel move freely in turn until the applied tension reaches the design value, and the construction is completed. Thus, a multi barrel embedded combined anchoring foundation is formed during construction.

The barrel is a hollow barrel, the outer side of the barrel is provided with a mooring hole, the bottom of the barrel is provided with an inward protruding card slot; The inner diameter of the innermost barrel is slightly larger than the outer diameter of the bucket foundation, and the card slot protruding from the bottom of the innermost barrel can cover the wall of the bucket foundation that number of seven, as shown in Fig. 1~Fig. 4. Preferably, the mooring hole of the innermost barrel should be set at the upper part of the outer side, so as to reduce the depth of the bayonet on the adjacent outer barrel.

![Fig. 1 Structure of innermost barrel](image1)
![Fig. 2 Structure of non innermost barrel](image2)
![Fig. 3 bucket foundation connection details](image3)
![Fig. 4 Detail of I-I section](image4)

The non innermost barrel needs to be provided with bayonets so that the mooring holes on all the barrels embedded in it can extend out of the barrel wall, as shown in Fig. 1. If there are multiple mooring holes on the inner barrel or semi-circular barrel, multiple bayonets shall be set on the adjacent outer barrel.
In each barrel of the anchored foundation: the inner diameter of the outer barrel is slightly larger than the outer diameter of the adjacent inner barrel, and the he card slot protruding from the bottom of the outer barrel can cover the wall of the adjacent inner barrel, as shown in the fig and Fig.2. It can be seen that when the barrels are embedded and stacked, the connection and load transfer between adjacent barrels are realized by the card slot. Therefore, the thickness and strength of the card slot should be large enough to meet the needs of stress transmission during penetration construction.

3. The proposed construction method of composite anchor

The bucket foundation is adopted for the construction of the multi barrel embedded combined anchoring foundation. The construction steps are as follows:

(1) Connecting the anchoring foundation

During construction, each barrel is interbedded and stacked according to the diameter relationship of each barrel, so that the bottom of the inner barrel is pressed on the card slot of the adjacent outer barrel, and the mooring hole on the inner barrel extends out based on the bayonet on the outer barrel. The mooring holes of each barrel are connected with steel cables from inside to outside in order to make each barrel form a series shape, and mooring one end of the chain to the mooring hole of the innermost barrel. Then the bottom of the bucket foundation is embedded in the innermost barrel and pressed on the card slot of the innermost barrel, as shown in Fig. 3 and Fig. 4.

Auxiliary measures should be taken to simply fix each barrel and bucket foundation, so that they will not be loose during construction. For example, the engineering glue with lower strength can be used for simple adhesion, and the subsequent barrels can break the engineering glue and separate each other under the action of anchor chain tension. Some auxiliary components are also needed to realize the subsequent detachable fixation and connection between the anchoring foundation and bucket foundation.

(2) The bucket foundation contacts the seabed by self weight

The bucket foundation is hoisted to enter the sea water and be in the state of plumb. The bucket foundation is gradually lowered to make it sink under the action of self weight, contact the seabed and press into the seabed to a certain depth, as shown in Fig. 5.

(3) The bucket foundation is penetrated into the seabed by suction

The top of the bucket foundation is provided with a water (gas) inlet valve, which fixedly connects the connecting pipe with the water (gas) inlet valve, the air inside the bucket foundation is pumped out through the connecting pipe to form the internal and external pressure difference, so that the bucket foundation can be penetrated into the seabed soil. Finally, the bottom anchoring foundation of the bucket foundation is pressed into the seabed soil to the design depth, as shown in Fig.6.

The anchoring foundation is composed of a plurality of circular barrels and semi-circular barrels in series, during the construction, the components are embedded, stacked and close together, and the area along the penetration direction is very small. It is more convenient to use bucket foundation for penetration construction, and the resistance is relatively small.
(4) Remove bucket foundation
Remove the bucket foundation. After the anchoring foundation is pressed into the seabed to the design depth, loosen the connection between the anchoring foundation and the bucket foundation to make the anchoring foundation separate from the bucket foundation. Through the connecting pipe to inflate the bucket foundation, the bucket foundation gradually floats up, and finally the bucket foundation is lifted and removed. After the bucket foundation is removed, only the anchoring foundation is left in the seabed soil, as shown in Fig. 7.

(5) Tension the anchor chain to make the anchoring foundation meet the design requirements
The tension is applied to the anchor chain to make each barrel separate from each other and move freely until the applied tension reaches the design value, and the construction is completed, thus forming a suction penetration assembled anchoring foundation, as shown in Fig. 8.

The tension of the anchor chain is gradually transferred from the top barrel to the bottom barrel, that is, the tension of the anchor chain minus the resistance of the top barrel will be transferred to the second barrel, the tension of the anchor chain minus the resistance of the top barrel and the second barrel will be transferred to the third barrel, and so on. It can be seen that the top barrel is the most loaded, and its uplift bearing capacity is consumed first, so its movement range is the largest, and the load and movement range from top to bottom decrease gradually. Therefore, before the anchoring foundation fails, the displacement attitude of each barrel is generally different, and the tension direction of the anchor chain changes all the time. Therefore, the attitude of each barrel is difficult to predict in practice, and only one of its possible working states is shown in Fig. 8. The larger the position and attitude difference of each barrel, the more complex the overall contact relationship between the barrel and the seabed soil, and the greater the friction and resistance between the barrel and the soil, which can increase the friction with the seabed soil as much as possible, thus improving the overall uplift bearing capacity of the anchoring foundation.

4. Conclusion
In this paper, a kind of multi barrel embedded combined anchoring foundation is proposed, which includes not less than two barrels. A mooring hole is arranged on the outside of the barrel, and a slot protruding inward is arranged on the bottom of the barrel. During the construction, the bottom of the inner barrel is pressed on the slot of the adjacent outer barrel according to the diameter relationship of each barrel, and the mooring holes of each barrel are connected with steel cables to form a series shape. The anchor chain is moored on the mooring hole of the innermost barrel, and then the bottom of the bucket foundation is embedded in the innermost barrel and pressed on the slot, and the anchoring foundation is penetrated by the bucket foundation When the design depth of seabed is reached, the bucket foundation is removed, and the tension is applied to the anchor chain to reach the design value, the construction is completed. Under the action of anchor chain tension, each barrel will move freely,
and the attitude of each barrel is not the same, which can increase the friction with the seabed soil, thus improving the uplift bearing capacity of the mooring foundation.

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