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Training Manual
on

Cage Culture
of
Marine Finfishes

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Engineering aspects of cage design, mooring and net design for open sea cage farming in India

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Introduction

Cage is an aquaculture production structure comprising of a rigid floating frame, flexible net materials and mooring system (synthetic mooring rope, buoy and anchor) with a round or square shape floating net pen to hold and culture large number of fishes and other aquatic resources which can be installed in reservoir, river, lake or sea. The design and operating variables in engineering aspects of an open sea cage is of great concern in mariculture operations as they are installed in exposed sites in the off shore areas. The design of the cage and its accessories is specially made in agreement to the individual farmer's requirements. A well engineered cage design will provide the opportunity to reduce the cost of the cages. HDPE material is found to be suitable to make cage frame for open sea cages. The HDPE float frames installed in open unprotected water can withstand wave conditions. Round cage (volume depends on diameter) with floatation system made of butt-welded HDPE pipes, designed for the culture of fishes such as milkfish, mullet, cobia or pompano, sea bass and lobsters, and this very well used in many countries. However, the sea is perhaps the most difficult environment for engineering operations. The sea generates great storm forces on any floating or sea bed mounted structure and the storm events occur randomly. The constant 24 hour per day bending compression and tension within structural member are optimum conditions for fatigue. Similarly constant motion in a corrosive fluid is ideal for mechanical wear and corrosion. Repairs and salvages are more difficult and in some cases access may be denied to some structures during a storm. Because of all these reasons the design of an aquaculture cage system is very complex in nature and of-course the most difficult task. Hence, it is essential to select a proper site, ideal construction materials and proper designing, suitable mooring and good management in bringing out cage culture production more viable, economical and profitable. The cage frame and nets used for cages has to withstand all types of weather conditions in the entire year. Next to frame, net is another important component in the cage and damage of the net is an important source of fish loss in cage culture systems. Thus, many considerations are to be taken into account while making a net for a specific purpose including forces applying on the net, kind net of materials, make of rope frame and the way in which the nets are tied. The main forces on any net structure are from winds, waves and currents and the interactions of the cage structure and its mooring systems with the resulting movements. Thus, cage systems in open sea are influenced by several prevailing conditions in the sea that may affect the safety of the system and cultivated fish species, if the system is not properly designed or engineered. Hence, cage design plays major role, because the designed cage need to withstand strong sea currents/ tidal flow and retain their effective volume; developing cages that should better suited to the sea conditions in different regions and to different species. In addition, it is also essential to implement well engineered design to lower the cost and increase the performance of the cage system. In this respect, the following factors are needed to be considered

Size of the cage

It is a fact that costs per unit volume decrease with increasing cage size, within the limits of the materials and construction methods used. However, very large cages may limit stocking, grading and harvesting options, and maintenance aspects like net changing and disease treatment also become increasingly difficult as size of cages increase. CMFRI has developed open sea cages of 6, 12 & 15 m dia for grow out fish culture and 2 m dia HDPE cages for seed rearing. However, the suggested ideal size for grow out cage is 6 m due to its easy manoeuvring and reduced labor. Presently, in India 6 m dia circular cages being popularly used in both west and east coasts.

Cage frame design

The design parameters for the cage frame are based on several earlier experiments of cage farming in India, as well as on guidelines from published studies. The size and shape of the cage were firstly defined by applying the criteria of Huguenin (1997) and Beveridge (1996), and the structure and floating system is defined on the basis of experience of Indian farms. The weight and flotation of the cage is calculated by applying formulas and data defined by Prado (1990). The current, wind and wave forces applied in the cage were calculated using the criteria of Milne (1972), Fridman (1986), Carson (1988) and Aarsnes *et al*. (1990). The cage frame may be of any shape such as circular, square, rectangular and octagonal shape. However, the circular shape is found to be more suitable as this shape makes the most efficient use of materials and thus reduce the costs per unit volume. Also, observations made on the swimming behavior of fish, suggest that circular shapes in a plane area are better in terms of utilization of space. Corners of other shapes (rectangular, square, and octagonal) are not properly utilized by the stocked fishes in the cage.

The cages are commonly made by three different materials, i.e High Density Poly Ethylene (HDPE) and Galvanized Iron (GI) and wooden bamboo poles. The HDPE cages are comparatively costlier than GI cages. However, business entrepreneurs with high capital investments can go for long lasting and expensive (HDPE) frames. Small groups and fishermen can opt for cost effective epoxy coated GI frames in sea and some extent wooden cages in brackish water creek areas. Moreover, the HDPE is best suitable material for the cage frame with respect to its durability and strength. The cage frame prepared using HDPE pipe is given as example and the specification of the material required for the six meter diameter cage frame is given in Table 1. The 6 m dia HDPE cage consisting of 6 m inner dia and 8 m outer dia frame material with provisions for connecting inner grow out and outer predator nets, respectively. The cage frame structure is the combination of different structures including, flotation pipes, collars and hand rails. The two floatation pipes (base pipes) generally filled with expanded polystyrene foam material to help for the more flotation of the pipes and also to avoid loss of floatation force in case of the pipe damages. The catwalk goes round the entire cage; the purpose is to supply support to the structure and to make maintenance, feeding, cleaning and other required activities easy. The hand rail is provided for the safety of the workers and to carry out easy way of routine cage management. The collars are another structure made by HDPE pipes used for maintaining the structure, and at the same time helps for flotation. The measurements of handrail and catwalk are according to the convenience of the fishermen. This catwalk can be built of polyethylene panels with stainless steel joints connected between the brackets. Ballast pipe is another structure used in the cage, which helps to keep the nets in proper position and serve as role of sinkers in fishing net. The ballast pipe is either filled with heavy materials or made with the holes for the free flow of the water to increase the weight of the ballast, and some time uses iron ropes inside pipe for increasing the weight. While making cage, the end of the base pipe is joined by welding process used for plastics. The two pipe rings for flotation and brackets will join the handrail. These brackets will give support to the rings and at the same time, it will form part of the catwalk. The brackets will be made of galvanized steel to avoid corrosion and be fitted to the diameter of the pipes. At the same time, these connections hold the brackets in their place to avoid movements in the rings and loss of shape.

Table 1. Specifications of material required for six meter diameter cage frame

Cage Part	Specification	HDPE pipe (outer dia)	HDPE Pipe (inner dia)	Thickness of Pipe	Circumf-erence / Length	Total require -ment
Outer collar	PE100 PN 10 IS 4984	140 mm	126 mm	16 mm	8 m dia	25.12 m
Inner collar	PE100 PN 10 IS 4984	140 mm	126 mm	16 mm	6 m dia	18.84 m
Middle support collar	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	5.5 m dia	17.27 m
Hand rail	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	6 m dia	18.84 m
Base Bracket Support	PE100 PN 10 IS 4984	250 mm	228 mm	22 mm	1.2 m	9.6 m
Base bracket vertical Support	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	0.7 m	5.6 m
Diagonal support	PE100 PN 10 IS 4984	90 m	78 mm	12 mm	1.2 m	9.6 m
Injection moulded machined "T" joints	PE63 PN 10 IS 4984	110 mm	92 mm	18 mm	NA	26 nos.
Injection moulded Long neck collar flange	PE63 PN 10 IS 4984	110 mm	90 mm	20 mm	NA	8 nos
Mooring clamps	Hot dip galvanized iron clamps	NA	NA	12 mm	140 mm OD	3
Nut & bolts	High tensile, tested SS material	NA	NA	25 mm	NA	6
Butt welding supporting base floating collar clamps	2 hot dip galvanized iron clamps	NA	NA	8 mm	NA	4
Butt welding supporting base floating collar clamp nut& bolts	High tensile SS material	NA	NA	16 mm	NA	8
Joint supporting nut & bolts	High tensile SS material	NA	NA	18 mm	NA	52
Longneck Bird net hooks	GI	NA	NA	22 mm	NA	8

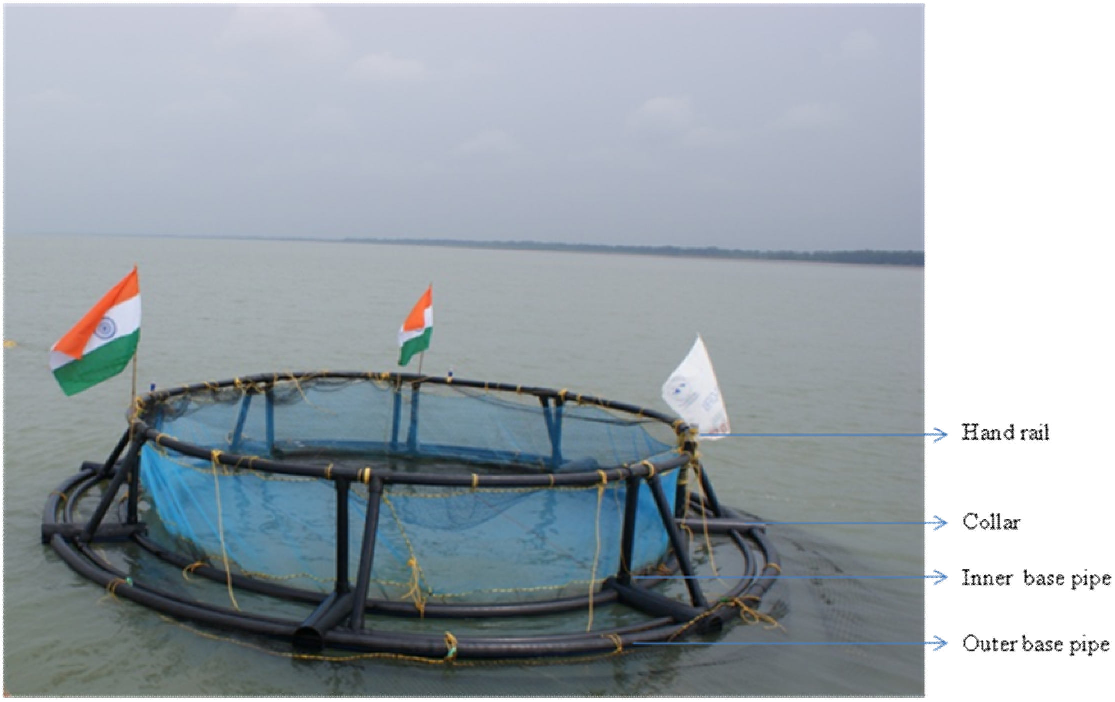


Fig.1. View of 6 m diameter HDPE floating cage

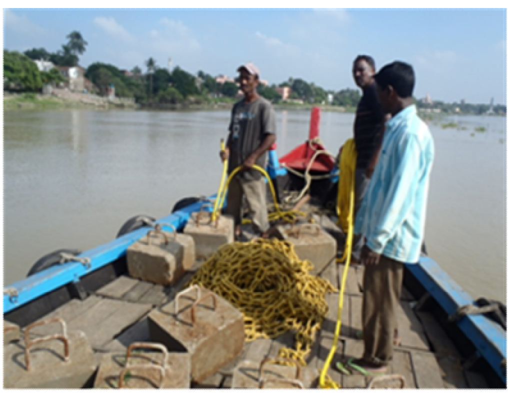
Mooring system

The mooring system holds the cage in the suitable position according to the direction and depth decided in the design, and sometimes this helps to maintain the shape of the cage. The mooring joins the cage at the anchor system. A mooring system must be powerful enough to resist the worst possible combination of the forces of currents, wind and waves without moving or breaking up. The materials used in the mooring systems are sea steel lines, chains, reinforced plastic ropes and mechanical connectors. The mooring force capacity depends on both the material and size, and can be adjusted to the requirements. Attachment to the system is by metallic connectors and ties. It offers operational advantages since it allows the cage to drift around the anchor with the current to the point of least resistance, which exerts the least force on the system. This movement allows the cage to have wide area of seabed and by which it could reduce the accumulated waste and pollution problems. Preliminary analysis of the benefits of this system indicates a 2 to 70 fold reduction in deposition of waste on the seabed, depending on mooring geometry and current type.

Mooring system used in most of the Indian cages consisting of 14 mm GI moulded link chain, swivels, C hook, 4 mm U shackles, barrels and cement blocks. C hook or U shackles connect anchor to the GI link chain and swivels is used 5-6 from the anchor, which helps to rotate the cage according to the different force. A cement block of 100-150 kg is used 2-3 m away from cage in mooring system as shock absorber; this system ensures soft movements of the cage with the currents by absorbing possible shocks. The vertical position of the weights depends on the forces acting upon it, thus acting like a shock absorber. In mooring system 2-3 barrels filled with air is used as floating system to identify mooring line. The required depth of the water column for efficient mooring is 12 m and 10 m during high and low tides respectively, with mud-sandy bottom.

Anchor system

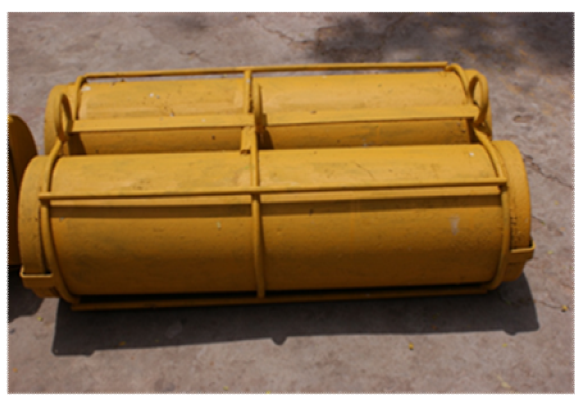
The anchor system holds the cage and all other components of cage in a particular site in the seabed and is connected to the cage by the mooring system. There are basically three types of anchors used: pile anchors, dead weight anchors and anchors that get their strength by engaging with the seabed. Pile anchors are buried piles in the seabed, they are effective, especially for systems where a small space is necessary, they are driven into the seabed usually by a pile hammer from a barge on the surface; but, they are expensive to buy and install. Dead weight anchors are usually concrete blocks, and the advantage of the system is that they are fairly consistent in holding power. Hard sand, rock or gravel make no difference to concrete blocks, they can resist at least their own weight in water in soft seabed conditions. This system can hold more than 3-5 times of their own weight under any condition. The third type is mooring anchors; this has to hold into a particular seabed when pulled from one direction only; they are made of steel and should slip easily into the seabed without disturbing the soil. The holding power of the anchor could be increased enormously, if the substrate is compact. All type of anchors is joined to the mooring system usually by chains and metallic connectors. In the east coast of Indian seas, different types of anchors were tried by CMFRI. Presently, dead weight anchor is mostly recommended for its strength and their easy deployment. The concrete blocks (100-150 Kg each) of 10-12 joined together by chains to provide appropriate strength and connected to a buoy by a braided rope. Several concrete blocks instead of one make the building, moving and setting of the system easy and also, this allows to have several points of anchoring. The chain used to connect the anchors to cage is of 1.3 cm is size with 80 grade strength. This specification of the chain is found to be suitable for the prevalent sea condition in the east coast.



Concrete block

Revolving swivel

Mooring chain



Puff filled buoy to hold the mooring chain

Fig.2. Components of mooring system

Net design

The cage bag is a flexible mesh material, which can be prepared by the different synthetic materials, including polyethylene (PE)/ High Density Poly Ethylene (HDPE), polyester (PES) and polypropylene (PP) or polyamide (PA). Among all, the PE material offers economic and technical advantages such as breaking strength, resistance to fouling and resistance to abrasion. The shape of the cage bag is cylindrical with a bottom lid. There are two net bags are used in a cage, i.e., inner and outer net bags. The mesh size of the both net bags are differs and it is majorly depends on the type and size of the fish planned for the culture. The square shaped mesh size is always preferred and to get the proper shape the net panel is attached to head rope with a hanging ratio (E) of 0.71 to produce square meshes, which helps against fouling and provides maximum surface area. Proper mesh size helps for free flows of water, which helps to maintain good water quality and finally it helps to reduce stress, improve feed conversion of the fish in the system. The net material impregnated with a special anti bio-fouling material helps to prevent growth of algae.

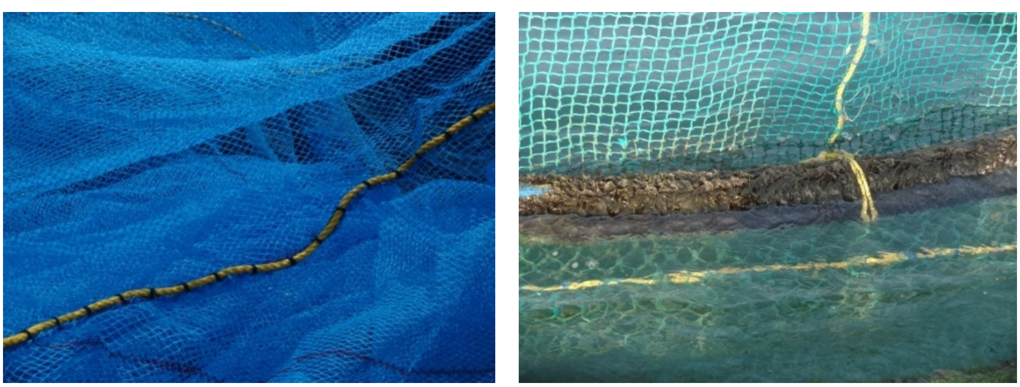


Fig.3. commonly used inner and outer nets in cages

While preparing net bags, eight crisscross ropes are provided in net bag to strengthen the net bag. The inner net bag is fitted to the upper side handrail and lower inner collar by the help of rope, which holds net in cylindrical shape. The outer net bag is fixed to the outer collar of cage. The bottom of the inner net bag is provided with ballast pipe for maintaining the shape of cage. A bird net is fixed to the top of the cage frame (hand rail) to avoid the menace of birds.

Table.2. Specifications of nets for a cage of 6 m dia. and 6 m depth used for fish culture

Name of the net	Material Specification	Twine size	Mesh size	Depth of the Net	Net bag diameter
Outer net	HDPE braided	4 mm	90 mm	6.25 m	6.75 m
Inner net	HDPE Sapphire	2 mm	20 mm	6.70 m	6.0 m
Juvenile net (Seed net)	HDPE Sapphire	1.5 mm	12 mm	3.0 m	6.0 m
Bird protection net	HDPE	1 mm	90 mm	NA	6.0 m

Nets of varying dimensions made by different materials were tested for cage culture in India. After the through research, CMFRI has suggested to use braided and twisted HDPE nets for grow out purpose. It can last for more than two years. Nylon net can be used economically, but since it is light weight, to hold the shape intact more weight has to be loaded in the ballast pipe. The commonly used depth for the net ranging from 2 to 4 m for fingerlings and 5 to 6 m for grow out cages. For open sea cage culture, predator net is compulsorily recommended to prevent the attack by predatory organisms.

Suggested readings:

Aarsnes, J.V, Rudi, H, Loland ,G.1990. Current forces on cage, net deflection. In: Osborn HD, Eadie HS, Funnell C, Kuo C, Linfoot BT (eds), *Engineering* for Offshore Fish Farming. Thomas Telford, London, pp. 137–152.

Baldwin K, Celikkol B, Steen R, Michelin D, Muller E, Lavoie P. 1999. Open ocean aquaculture engineering: mooring & net pen deployment. Mar Technol Soc j. 34: pp.

Beveridge, M .C. 1996. Cage Aquaculture. 2nd ed. Fishing New Books Ltd., Oxford, U.K., pp. 346.

Cairns J, Linfoot B. 1990. Some considerations in the structural engineering of sea-cages for aquaculture. In: Engineering for Offshore Fish Farming. Thomas telford ed. London, pp. 63-77.

Carson R M. 1988. Engineering analysis and design of cage systems for exposed locations. In: Aquaculture engineering technologies for the future. Papers from symposium held at the University of Stirling, Scotland. EFCE Publication no. 56, Hemisphere Publishing Corp., New York. London, pp. 77-96.

Fredriksson DW. 2001. Open ocean fish cage and mooring system dynamics. PhD Thesis. University of New Hampshire, Durham, NH.

Fredriksson, D.W., Swift, M.R., Irish, J.D., Tsukrov ,I and Celikkol, B. 2003. Fish cage and mooring system dynamics using physical and numerical models with field measurements. Aquacult. Eng., 27: pp. 117–146.