Chapter 17
Evolution of "Floating Fish Cages for Inland Waters" Developed by RuTAG IIT Bombay

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1 Introduction

Cage fishing/Aquaculture is the process of controlled and protective rearing of fries to fingerlings within a "cage" (a net that allows water flow) floating in a water body. The inland aquaculture culture in India is relatively new but the origin of cages for holding and transportation for short time can be seen two centuries ago in the Asian region [1]. In India, cage culture was initiated in an inland water body for raising carps in Allahabad and producing the carp snakes heads and tilapia in Karnataka [2]. After that cages have been used in many reservoirs and floodplains for rearing fry to produce advance fingerlings for stocking in main water bodies [3].

The fish cage culture in Dimbhe dam of Pune district, Maharashtra started in 2007 with help of Central Institute of Fisheries Education (CIFE) Mumbai. The local fisherman cooperative society had started producing fingerlings from fry. Fingerlings, and then it is released into the water for increasing stocking density. This practice increased the production of fish from the reservoir, as well as the income of fisherman-associated fisherman society. There were some problems associated with CIFE cages, which will be discussed later. The need came from stakeholders for modified cages and they approached RuTAG IIT Bombay for the same. RuTAG worked on the design of new cages and come up with sturdier and robust design.

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This study focuses on the tracing the history of fish cage culture at Dimbhe and need of design modification of cages. It also focuses on the journey of RuTAG to finalize the design for easier operation and maintenance.

The paper includes the brief introduction of NGO Shashwat and history of cage culture in Dimbhe dam reservoir. It also focuses on the study of the original design of fish cages and drawback of same. Then, it includes the approach and methodology of RuTAG IIT Bombay for finalizing new cage design and compares new RuTAG design with original design installed by CIFE. The study includes features of "Floating fish cages for inland waters" developed by RuTAG IIT Bombay, its impact and dissemination efforts in India.

2 Problem Identification

2.1 Description of Original Design

As mentioned earlier, NGO Shashwat started aquaculture in Dimbhe dam reservoir in 2007 and CIFE, Mumbai helped them to start the practice. CIFE introduced wooden cages as shown in Fig. 1. The fish cages were made up of sal wood, hooks, and drums. Each battery of fish cages consists of four cages of size 3 m * 3 m as shown in Fig. 1.

Fig. 1 Fish cages developed by CIFE, Mumbai

2.2 Components/Parts Used in CIFE Fish Cages

Wood: Locally available wood is used for making truss. The wooden frame of the rectangular cross section is used for fabrication of the basic structure. After fabrication of wooden frame, planks are fixed on the frame with help of nails.

Hooks: The hooks are fixed to wooden frame with help of bolts for holding the fish cage nets. The inverted hooks of J-shaped fixed as shown in the figure.

Drums: Drums are used to provide the buoyancy force for floating. Airtight drums are placed uniformly around the structure at every joint. A total of nine drums are used and fixed with the wooden frame using bolts.

2.3 Problems Associated with CIFE Fish Cages

Failure of the Walkway: Walkway way is made up of wooden planks and fixed on a wooden frame with nails. Due to the water waves, the PVC barrels which are used for floating the structure continuously hit the wooden truss and walkway planks and also loosen the connecting bolts, and nails used in assembly. Due to loosening of nails and decomposition of planks, the water walkway planks breaks and fails. Also due to humidity and water waves, the walkway can become slippery, which makes working on walkway difficult.

Sagging of the Walkway: The walkway sags heavily along its length which makes walking on it and operating the cages very difficult. The primary reason for sagging of walkway is low buoyancy force by the floating drums. To avoid sagging of walkway drums, more drums should be used and placed in the middle of the walkway.

Failure of the Drum: Vertical thrust due to water waves and wind, drums constantly hits the walkways which result in failure of drums. It is difficult in the design to change the drum due to complexity in holding the drums in structure.

Corrosion: Hooks, bolts, and nails used in the assembly of the cage are corroded rapidly due to contact with water and humidity. The hooks are placed on the walkway as shown in figure increases the chance of injury due to hooks and corrosion may increase the fatal.

Failure due to heavy wind and water waves: Continuous waves and heavy wind can damage structure easily. Due to waves cage structure can be immersed in water and there are chances that fish from the cages can go out with water outside the cages. This can affect financially to the fisherman society.

Moving fish cages inside the dam: The whole structure is too heavy for pulling by a small motorboat (available to the fishing cooperative). The whole cage structure needs to be shifted whenever there is a significant shift in the shoreline. There are chances of failure while shifting from one place to another due to weak joints in structure.

On the basis of the above study, the following objectives were proposed:

1. To design the floating structure for cages that would give the minimum installation plus operations/maintenance cost (two alternative designs)
2. To reduce the impacting of the barrels on the main structure or the walkway
3. To minimize the sagging of the walkways
4. To check the effectiveness and durability of the proposed design(s) through on-site implementation and regular operation for one year.

3 New Design

3.1 Approach

The study of CIFE fish cage structure and problems associated with it helped in deciding the approach to design a new product. While designing, new product of the following constraints was taken into account.

Availability of material: Most important factors is considered while fabricating fish cages. The material used for fabrication must be easily available in the market. GI round pipes are easily available in the market, as well as bolts and FRP gratings are available in standard sizes. MS flats for drum tighteners can also be bought from market easily.

Manufacturing: The operations involved in the manufacturing of "floating fish cages for inland waters" developed by RuTAG are cutting, threading, bending, boring, and welding. These operations can be performed at any fabrication workshop with minimum facilities.

Transportation: The structure consists of small parts and it can easily be transported to remote locations. Due to the relatively compact size of parts, it requires a small volume in the vehicle.

Assembly and installation: Threading and small parts of the pipe increases the time required for assembly and installation but no fabrication or electricity needed on-site while assembling structure makes it more convenient to install at remote locations.

Maintenance: Drums can be pulled out easily due to the use of drum tighteners hence easy for maintenance. Also, the structure can be shifted inside the water body from one place to another without damage due to sturdier design and lighter weight as compared to CIFE cages.

Endurance: Endurance due to waves and wind is very high and safe working on walkway even for the person who is not used to work on it.

3.2 Methodology

Based on the objectives, two alternative designs of fish cages were proposed which gives minimum installation and maintenance cost. For validating structural stability, the designs are modeled and analyzed in the software SAP2000 which is structural software for analysis and design. While analyzing the structural stability the properties of the material are also considered. A drum is replaced with four springs of effective stiffness of 1.1173 kN/m, which provides vertically upward force to act as buoyancy force. Effective stiffness of the spring is the slope of the linear fit of the force–displacement curve which is calculated using the method of least squares. Three load cases were taken as displacement due to self-weight of structure, displacement due to 30 people of weight 85 kg each standing of structure uniformly, and displacement due to 10 people of weight 85 kg each standing on one corner of the cage. The results of this will be discussed later.

The final design is discussed with fabricator and fabrication is done. After fabrication, on-site assembly was done and cages are installed in Dimbhe dam reservoir. The design is then tested in the field for all the abovementioned cases after observation of the expected results cages were handover to fisherman cooperative society for use.

During the year of operation from installation, continuous feedback was taken from the society member also field visits were conducted for observation and performance testing. After 1 year of observations and feedback, minor changes were identified, which will then be incorporated in the next model during fish cage dissemination project of Government of Maharashtra.

3.3 Description of New Design

Initially, two designs of fish cages were proposed as shown in Figs. 2 and 3 and analyzed on SAP 2000, and the results of which are given in Table 1.

On the basis of the above results, the fixed truss model without diagonal, i.e., model A is finalized. The fish cages installed at Dimbhe required different components such as GI pipes, coupling and union joints, drums, FRP gratings, drum tighteners, etc.,

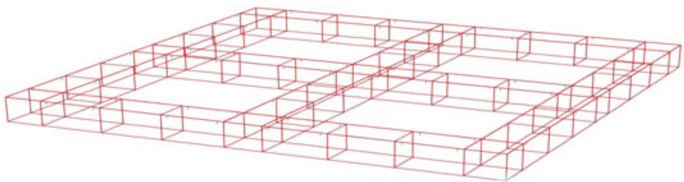

Fig. 2 Schematic of the fixed truss model without diagonals (Model A)

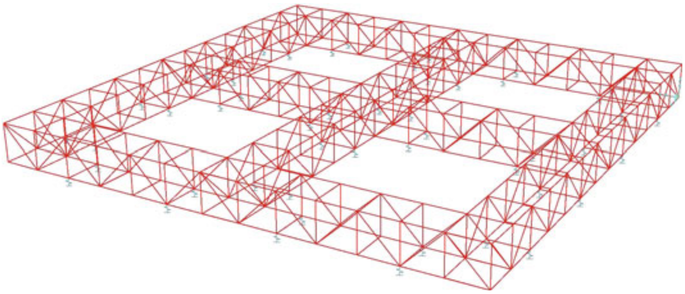

Fig. 3 Schematic of the pinned truss model with diagonals (Model B)

Table 1 Displacement of structure in different cases

Sr. no	Load combination	Pinned truss with diagonals (m)	Fixed truss without diagonals (m)
1	Self-weight	0.0883	0.0607
2	30 people standing uniformly	0.3787	0.2984
3	10 people standing at the corner	0.5375	0.5696

Fig. 4 Final design of fish cages installed at Dimbhe dam reservoir

which will be discussed later. The original floating fish cage structure installed is shown in the diagram given (Fig. 4).

3.4 Components Used in New Design

Figure 5 shows the different components used in assembly. The main components in the assembly are described individually as given below:

GI pipes: Class C pipes (1-in. nominal bore) are used in assembly. Three different lengths of pipes used are 958, 465, and 271 mm. All the pipes are threaded on both sides with 1-in. standard BSP threads on 16 mm length. The reason behind choosing GI pipe was to avoid rusting and increase life of the structure.

FRP gratings: Two sizes of FRP gratings are required with square holes of size 3 cm * 3 cm on it. The thickness of grating is 2.5 cm (1 in.). The grid is chosen over the solid walkway to allow the flow of water through the walkway, thereby reducing the impact due to the water on the structure and also reduce the material cost and the weight of the structure (Fig. 6).

Couplings and Union joints: Couplings are used to create "fixed" joints. The couplings are made of mild steel and need to be galvanized to prevent corrosion. There are four kinds of couplings used in structure as 3 way, 4 way, 5 way, and 6 way as shown in Fig. 7.

Drums: The PVC barrels are recycled and used as devices for floating the structure. The length of the drum is 975 mm and the diameter varies along the length. They need to be made air tight after recycling to prevent the water from entering. The dimensions and different views are shown in the following Fig. 8.

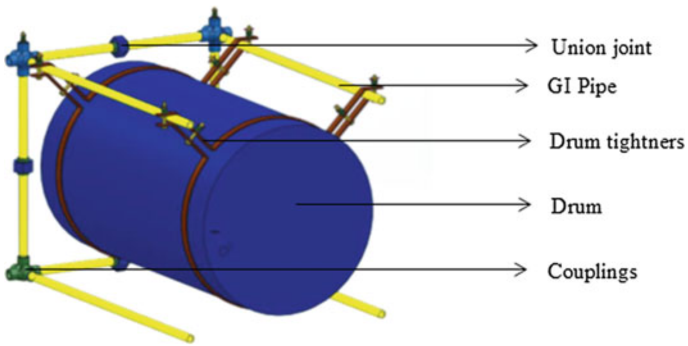

Fig. 5 Components used in RuTAG design

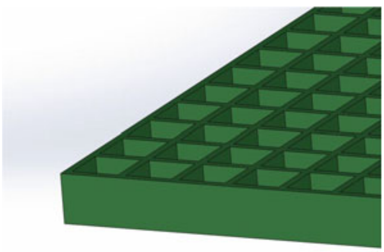

Fig. 6 FRP grating

Fig. 7 Types of coupling used

Drum tighteners and rubber tubes: There is a pair of drum tighteners for each drum, which is used to connect the drums to the structure and also to tighten the drum connection. It is made of mild steel flat and galvanized to prevent corrosion. The thickness of the tighteners is 5 mm and the width is 25 mm. The following Fig. 9 illustrate the drum tightener and the way it is connected to the drum. Rubber tubes are cut and inserted in between drum tighteners and drum to use as a damper for vibrations created by wind and water waves.

Angles: Angles are used as supports for the walkway. The angles are connected to the couplings using bolts and the grating is placed on the angles. 40 × 40 × 5 angles are used in different combinations and lengths. The different shapes are created using welding and are given a fusion bonded epoxy coating to prevent corrosion.

Net holders: Hooks are connected to the L-shaped Inner angle through bolts. The nets used for the cage fishing are tied to the structure through these hooks. The following figures illustrate the Hooks and the connection to the L-shaped Inner angle. The spacing between the hooks is 1 m (Fig. 10).

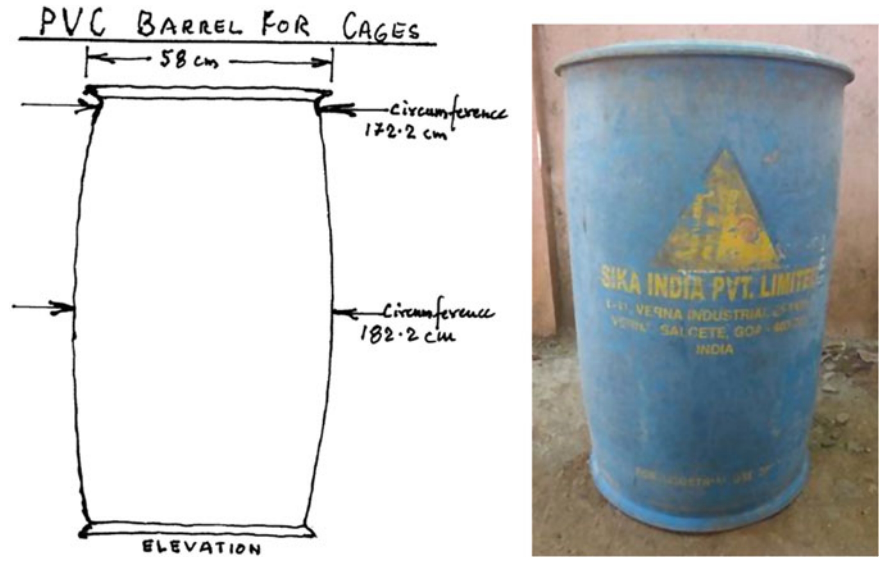

Fig. 8 Drums

Fig. 9 Drum tighteners

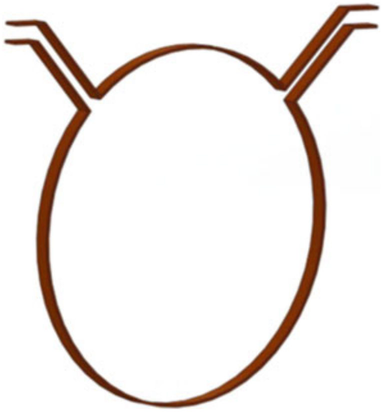

Fig. 10 Hook as net holder

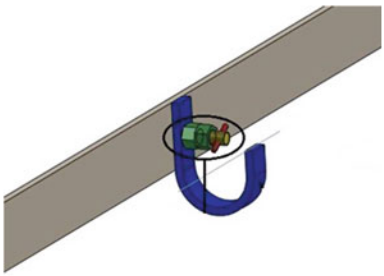

Table 2 Comparison of CIFE and RuTAG fish cages

Sr. no	Parameter	CIFE, Mumbai cages	RuTAG IIT Bombay cages
1	Shape	Square	Square
2	Dimension	3 m * 3 m * 3 m per cage	3 m * 3 m * 3 m per cage
3	Volume	27 cubic meters in each cage	27 cubic meters in each cage
4	Basic structure	Wood	Galvanized iron pipes
5	Walkways	Narrow and made up of Wooden flanks	Broad walkway and made up of FRP gratings
6	Joints	MS bolts and iron Nails	Couplings and union joints
7	Net holders	MS hooks which can harm person working on walkway	MS galvanized hooks fixed on inner part of cage
8	Drums	Nine drums are used which is not sufficient for providing safe buoyancy force	24 drums are used which make structure sturdier and safe for working on it
9	Drum holders	Wood and bolts are used as drum holder. It does not provide enough grip to avoid hitting drum on a walkway	Specially designed drum tighteners are used which avoids hitting of drum to walkway to prevent fatigue
10	Transportation	Difficult to carry due to bulky volume and high weight	Easy to carry due to separate parts and lighter weight
11	Maintenance	High maintenance	Low maintenance
12	Endurance	Low	High

Bolts and Nuts: Bolts' set consists of a bolt, a couple of nuts, and a pin. There are four different kinds of bolts' sets used in the structure. All the bolts, nuts, pins, and holders are made of mild steel and galvanized before to prevent corrosion. With every bolt, a pair of nuts is used to prevent self-loosening and avoid fatigue.

3.5 Comparison of Cages

CIFE and RuTAG IIT Bombay fish cage designs are compared with each other on the basis of different parameters as shown in Table 2.

4 Results and Conclusions

The "floating fish cages for inland waters" developed by RuTAG IIT Bombay has impacted local fisherman cooperative society in terms of livelihood generation, increasing women participation in cage fishing due to increase in safety factor [4]. NGO Shashwat has earned a name in one of the few practitioners in Maharashtra for cage fishing and giving training to fisherman interested in cage fishing. Some of the salient features of the new design are mentioned below:

- Safe and robust structure can take a load of 30 persons easily.
- Simple and modular design.
- Easy to maintain and low operational cost.
- Broad walkways improved safety in operations of cleaning.

After intervention in Dimbhe dam, the design was appreciated by the local fishing community. NGO Shashwat proposed Government of Maharashtra for the replication of same structure in the nearby dam and 28 more cages were installed in nearby dams with funding from Tribal Development Department (TDD), Government of Maharashtra.

In 2017, Office of Principal Scientific Advisor, Government of India proposed Ministry of Development of Northeast Region (DONER) about replication of fish cage structures developed by RuTAG IIT Bombay. The Ministry of DONER then approved and funded a project for the replication of 200 fish cages in Northeast India.

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Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants included in the study.

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