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Note

Monitoring of Floating Fish Reef Installed in Koje Coastal Waters

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Abstract : This paper describes a floating fish reef technology for enhancement of fisheries productivity in the muddy areas. The floating fish reef was composed of main fish cage, anchor rope and concrete anchor blocks. Main fish cage was made up of 12 steel buoys measuring 0.37 m in diameter and 1.5 m long, polyethylene (PE) netting and circular steel rings. Each steel buoy had buoyancy of 110 kgf. The size of main fish cage was 1.96 m in diameter and 3.75 m in length. Monitoring on its durability was made for eight months after installation. The steel buoys fixed on main fish cage and nettings were observed to be kept safely. The wet weight of fouling organisms per unit area (m^2) was 26.6 kgf after eight months. Reduction in the cross-section of steel buoys and circular steel rings of main fish cage were not found. In addition, any cracks on the concrete anchor blocks were not observed.

Key words : floating fish reef, fisheries productivity, muddy area, monitoring, durability, fouling organisms, cracks.

1. Introduction

Fisheries production in the Korean coastal zones has decreased recently due to overfishing, pollution, intensive aquaculture, and land reclamation. In addition, the proclamation of 200-mile Exclusive Economic Zones by many nations has made long-range fishing more difficult. Therefore the need for artificial reefs to increase productivity in the coastal waters has greatly increased in Korea (Kim *et al.* 1994). Many artificial reefs have been installed at the Korean coastal waters since 1970's. By 1999, reefs were installed at 1200 sites, and the total volume of them was about $7 \times 10^7 m^3$ (The Korean Ministry of Maritime Affairs & Fisheries 2000). As the installation of gravity reef (i. e., concrete reef) installation increases, sites (i. e., sandy or rocky areas) for its installation has decreased. Thus another fishing reef technology (e. g., floating fish cage) was needed for enhancement of fisheries productivity in the muddy areas where gravity reef can not be installed (Korean Fisheries Research & Development Institute 1998).

The floating fish reef is a kind of fishing tool to attract migratory fish like yellow tail and spotted mackerel. It is composed of floating units (main fish cage, subsidiary members), rope, anchor and connection section. As a floating fish reef is established in the open sea, it undergoes the external forces from strong wave or current and so on. The external forces cause the deterioration of the material and reduction in its cross-section. Any slackness of the anchor rope may cause damage to the connecting section or the anchor rope. Therefore the stability of the floating fish reef against the external forces depends upon how to identify and evaluate the critical external forces. As the critical external forces can be reflected as a value of design, stability of the floating fish reef in the sea is identified by its durability. This paper describes a floating fish reef technology in the muddy areas. It was focused on its durability.

2. Materials and methods

Shape of the floating fish reef

The floating fish reef was composed of main fish cage, anchor rope and concrete anchor blocks. The main fish cage was made up of 12 steel buoys measuring 0.37 m in diameter and 1.5 m long, polyethylene (PE) netting and

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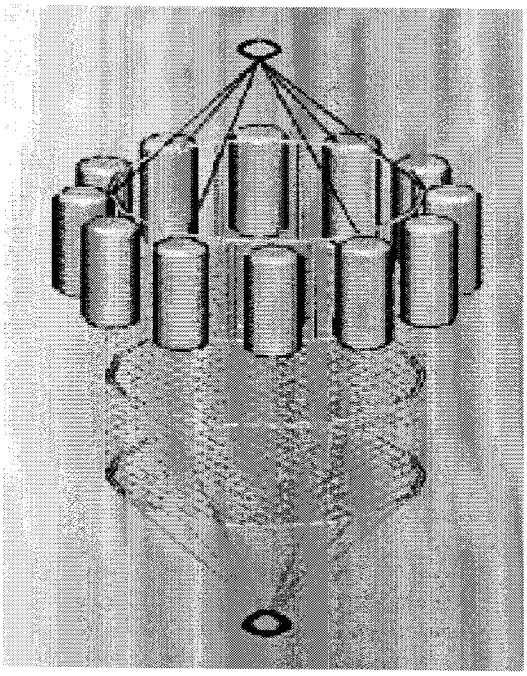

Fig. 1. Main fish cage.

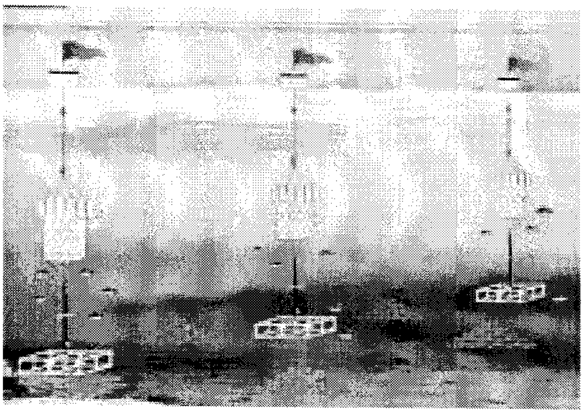

Fig. 2. Overall deployment of floating fish reef.

circular steel rings (Fig. 1). Each steel buoy had buoyancy of 110 kgf. The size of main fish cage was 1.96 m in diameter and 3.75 m in length. Anchor ropes were made up of PP rope of 40 mm in diameter, and steel U-shackle and swivel. Concrete blocks were used for anchor, which composed of two dice reefs with a dimension of 2 × 2 × 2 m (Fig. 2).

Design of a floating fish reef

Design factors

- Current (Uo) : 1.0 m/s
- Water depth (h) : 30 m
- Wave height (H) : 6 m
- Wave period (T) : 10.0 s
- Angle of slope of floating fish reef (φ) : less than 25°

Structural design

Design external force

Investigation of all the external forces acting on the floating fish reef both at the time of and after construction is necessary to identify and evaluate the critical external force. In this study the virtual weight of the total floating fish reef δ_G was calculated, considering the weight of the fouling organisms, with the following formula (1):

$$\delta_G = (W + W_B) / Vo \quad (1)$$

Where

W : Total weight of members, including anchor rope;

W_B : Weight of fouling organisms;

Vo : Total apparent volume of the floating fish reef.

The hydraulic force could be caused by current and buoyancy. The calculation of the hydraulic force caused by the current was done considering the increased cross section area of the member's and the excess load by the fouling organisms. The weight of the fouling organisms differed depending on the species of organisms, the material used for the floating (nets, buoys, rope), the place and depth in which reef was located. The weights were calculated by taking a value of design of ca. 50 kgf/m^2. The buoyancy was fixed in relation to the vertical forces such as dead weight of main fish cage, various fouling organisms, and anchor rope. Also the reduction in weight of the floating body caused by buoyancy was considered in calculation. When the free oscillation period of the floating structure was not greater than that of the wave, the angle of slope φ of the floating fish reef was calculated by the following formula (2):

$$\varphi = \tan^{-1}(F_0/N)$$

$$F_0 = \frac{w_0}{2g}(\sum C_D A)u_0^2 \quad (2)$$

$$N = (w_0 - \sigma_G)V$$

Where

N : Required surplus buoyancy;

σ_G, w_0 : Weight per unit volume of floating fish reef and sea water;

A : Area of the members of the floating fish reef which obstructs the flow;

u_0 : Current speed.

As there is no sympathetic resonance from the floating fish reef in response to the waves and current, the maximum horizontal force is obtained by the value of the currents (e.g. the ocean and wave currents). And the maximum vertical force is created only by the waves (All-Japan Association for the Development and Promotion of Coastal Industries 1994). When the anchor rope is at an angle only due to hydraulic force acting on the floating fish reef and F_w is the hydraulic force in the direction of the anchor rope caused by the waves, as the water depth at which floating fish reef is placed increases, the wave force was considered by the deepsea waves. The maximum water particle velocity of the deepsea wave in the direction of the anchor rope is v_m, if z is the measured water depth at which the floating fish cage hangs from the sea surface:

$$v_m = \pi \frac{H}{T} e^{-2\pi z/L}$$
$$F_D = C_D A \frac{w_0}{2g} v_m^2 \quad (3)$$
$$F_M = C_M \frac{2\pi w_0}{gT} v_m$$

The maximum value of the wave forces $(F_w)_{max}$ and the minimum value of $(F_w)_{min}$ were obtained from the formula (4)

$$\text{when } F_M > 2F_D$$
$$\{(F_w)_{max}, (F_w)_{min}\} = \pm F_M \quad (4)$$
$$\text{when } F_M \leq 2F_D$$
$$\{(F_w)_{max}, (F_w)_{min}\} = \pm\left(F_D + \frac{F_M^2}{4F_D}\right)$$

Anchor rope tension

The maximum tension in the anchor rope was obtained

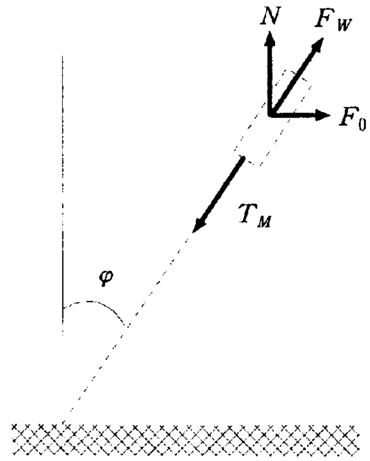

Fig. 3. Diagram of forces acting on a floating fish reef.

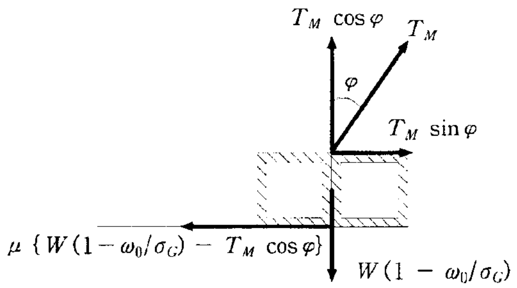

Fig. 4. Diagram of forces acting on the anchor block.

from the formula (5) by taking the sum of equilibrium force of the flow, required buoyancy obtained from the formula (2) and the change of tension in the direction of the anchor rope obtained from the formulae (2) and (3) (Figs. 3, 4):

$$T_M = N/\cos\varphi + (F_w)_{max} \quad (5)$$

Anchor

Concrete blocks were used as anchor maintain the floating fish reef. The weight of the anchor should be heavy enough not to move when the anchor rope was under maximum tension, and to develop frictional resistance to resist the horizontal pull at it, which was obtained from the following formula (6):

$$W \geq \frac{T_M(S_F \sin\varphi + \mu\cos\varphi)}{\mu(1 - w_0/\sigma_G)} \quad (6)$$

Where

W : Weight of anchor block in air;

σ_G : Weight per unit volume of floating fish reef (specific gravity);

μ : Coefficient of friction between anchor and sea bed (0.5-0.6);

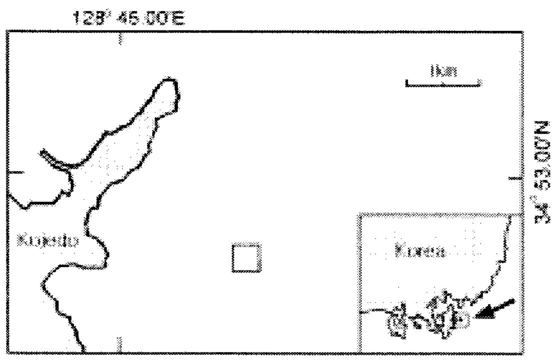

Fig. 5. Location of floating fish cage in Koje coastal area in Korea. Rectangular symbol indicates the location of the floating fish reef.

S_F : Safety factor (2.0);
T_M : Tension in anchor rope.

Installation of the floating fish reef

Twenty five floating fish reefs were installed in 16 hectares located in the northeastern of Koje Island in the depth of 30 m on November in 1999 (Fig. 5). The bottom sediment was mud. In general, the water depth at which a floating fish reef should be placed is 100-150 m or deeper and main fish cage within 30 m from the surface. But in this case main fish cage was placed within 15 m from the surface, because it was installed at the muddy area where concrete reefs can not be installed. Each reef was placed at a distance of 40 m (Fig. 2).

Monitoring of the floating fish reef

Middle layer gill nets were used for estimation of fish catch weight. Five gill nets were set with 7.5 outer-net-mesh, 36 middle-net-mesh, 2 m high and 30 m long. During fishing operation, underwater observations was also made for two to three days. The number of fish species around floating fish reef, fouling organisms and the durability of units or members of floating reefs were observed by divers equipped with SCUBA. Survey of durability includes (1) fixed condition of steel buoys on main fish cage, (2) wet weight of the fouling organisms on the steel buoys, (3) deterioration of the material and reduction in the cross-section (steel buoys and circular steel ring of main fish cage, U-shackle of rope, etc), (4) cracks of parts of concrete anchor blocks connected by anchor rope. Survey was made 3 times (May, August, November) in 2000.

3. Result and discussion

Number of fish species and fish catch weight around floating fish reef

The species number of fish found around the floating fish reef was two; slimy mackerel (*Scomber australasicus Cuvier*) and rock bream (*Oplegnathus fasciatus*). Slimy mackerel was observed at a distance of about 20 m from main fish cage. On the other hand, rock bream appeared close to it (Fig. 6). The biomass of fish catches per net in the floating fish cage was 108 gf.

Durability of floating fish reef

Stability of steel buoys and wet weight of fouling organisms on steel buoys

Steel buoys fixed on main fish cage and nets of main

Fig. 6. Group of rock bream (*Oplegnathus fasciatus*) attracted in a floating fish reef.

Fig. 7. Main fish cage of floating fish aggregator in water. It was made up of 12 steel buoys measuring 0.37 m in diameter and 1.5 m long, PE netting and cir-ular steel rings. It was taken from the bottom.

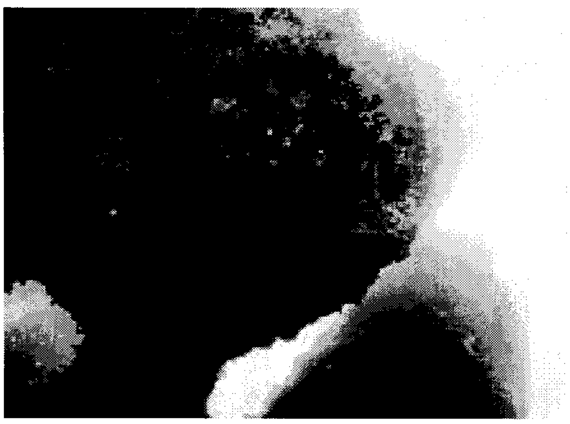

Fig. 8. Mussel (*Mytilus edulis*) attached on the steel buoys of main fish reef.

fish reef were found to be kept as it had been (Fig. 7). The wet weight of fouling organisms per unit area (m^2) was 4.6 kgf after six months, and 26.6 kgf after eight months. The weight was lower than that of the designed value, which calculated by taking a value of density of ca. 50 kgf/m^2. The dominant species of organisms attached to the steel buoys was mussel (*Mytilus edulis*). The mussel adhered to them down to the depth of 20 m from the surface after eight months (Fig. 8).

Fig. 9. U-shackles and swivels connected to anchor rope.

Fig. 10. Concrete anchor blocks connected by anchor rope. Two dice reefs (2 × 2 × 2 m) per a floating cage were used as gravity anchor.

Deterioration of the material and reduction in the cross-section

Reduction in the cross-section of steel buoys and circular steel rings of main fish cage were not found. As the structure of the connecting section such as U-shackles and swivels was frangible due to torsion or friction by a repeated load, it should be durable (Nakamura 1991; All-Japan Association for the Development and Promotion of Coastal Industries 1994). According to observation by divers equipped with SCUBA, a decrease in the cross-section of shackles and swivels connected to anchor rope was not observed (Fig. 9).

Cracks of concrete anchor blocks connected to anchor rope

Cracking will occur whenever the tensile strain to concrete exceeds the capacity of the concrete to resist it . The capacity varies with age and rate of application of strain. Concrete anchor blocks connected to the anchor rope are subjected to a concentrated load by all external forces where the floating fish reef is established, which cause cracks. If wide load-induced cracks are found, it indicates that the calculations for the ultimate limit state are incorrect. This may be due to the effects of a particular form of loading being misunderstood or neglected to the extent that no or insufficient reinforcement has been provided to resist a particular load effect (CEB 1992). However, in this study cracks on the concrete anchor blocks were not found (Fig. 10). It seemed that the tensile strain to the concrete anchor blocks did not exceed the capacity of the concrete to resist tensile strain.

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