ARTIFICIAL REEFS IN MALAYSIA : A Country Review Paper

BY

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1. INTRODUCTION

1.1 Background

The concept of artificial reefs being man – made objects intentionally placed on the sea bed to increase the abundance of fisheries resources has existed since the 18th century but the bulk of documented work was carried out in the late 1900s (Ino, 1974).

In Malaysia, the marine fisheries resources have declined considerably over the past decade due to the use of efficient gears which have had also damaging effects on the marine habitat. The decline in fisheries resources is reflected in catch data of research vessels monitoring the demersal resources of the coastal waters off the west coast of Peninsular Malaysia. The average catch rate of 131.1 kg/hr in December 1970 had decreased by 55% to only 58.9 kg/hr in December 1980. The average catch rate of trawlers in Peninsular Malaysia for 1986 was only 18.7 kg/hr (Department of Fisheries 1987).

The first artificial reef in Malaysia was established at Pulau Telur, Kedah in May 1975. The Fisheries Research Institute of the Department on Fisheries. Ministry of Agriculture initiated the programme to construct artificial reefs from used tyres. Subsequently two more artificial reefs were deployed at Pulau Payar, Kedah in October, 1975 and at Pulau Aman, Penang in July, 1976.

Initially, the project was carried out on an *ad hoc* basis on a modest scale and progressed gradually with borrowed facilities and manpower. As a result of encouraging ecological development around the artificial reefs and the rising need for the enhancement of fisheries resources in Malaysian waters, the artificial reef project was officially recognised as a fisheries development project of the Department of Fisheries, Ministry of Agriculture. During the Fifth Malaysian Plan (1986–1990) the project was allocated a budget of M$ 8.24 million.

1.2 Objectives

The primary objectives of this project are:–

a. to rehabilitate and conserve marine habitats that have been adversely affected by fishing activities such as trawling.

b. to help generate the recovery of coastal fisheries resources, thereby improving the catches of traditional inshore fishermen engaged in the use of artisanal gears.

c. to increase the biological productivity and fisheries resources in the coastal waters through the enhancement of marine ecosystems that serve as nursery and breeding grounds for fish and other marine organisms.

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2. STATUS OF THE GOVERNMENT PROGRAMME ON ARTIFICIAL REEFS

2.1 Location of artificial reefs

By the month of August 1989, a total of 65 artificial reefs constructed from scrap tyres had been established in Malaysia with the use of 1 029 406 tyres (Table 1). There are 52 artificial reefs in the coastal waters of Peninsular Malaysia while Sarawak and Sabah have 7 and 6 artificial reefs respectively (Fig. la & Fig. 1b)

In addition to the 65 tyre reefs in Malaysia, there are also 9 artificial reefs constructed from derelict/confiscated boats (7 boat reefs in Peninsular Malaysia and 2 boat reefs in Sarawak) (Table 2).

There are 4 concrete artificial reefs in the coasted waters of Peninsular Malaysia (2 sites on the west coast and 2 sites on the east coast). (Table 3).

Table 1. Construction of Artificial Reefs (tyres) in Malaysia.

YEAR	Pen. M'sia		Sabah		Sarawak	
	No. of reefs	No. of Tyres	No. of reefs	No. of Tyres	No. of reefs	No. of Tyres
1975	2	2602	–	–	–	–
1976	3	4432	–	–	–	–
1977	3	6626	–	–	–	–
1978	5	10042	–	–	–	–
1979	6	13592	–	–	–	–
1980	6	16848	–	–	–	–
1981	6	19486	–	–	–	–
1982	7	21244	3	7006	2	3392
1983	10	27260	3	7006	4	31009
1984	14	50778	5	24337	6	47124
1985	14	58734	5	31241	6	60324
1986	51	88519	6	43819	6	60324
1987	52	391865	7	53277	6	60324
1988	52	699582	7	53277	6	60324
1989	52	915805	7	53277	6	60324

Table 2. Construction of Artificial Reefs (boats) In Malaysia.

Year	No. of sites	Total no. of boats per site
1984	4	23
1985	6	60
1986	7	61
1987	9	77
1988	9	77
1989	9	77

Table 3. Construction of Artificial Reefs (concrete) In Malaysia.

Year	No. of sites	Total no. of concrete pyramid per site
1986	1	20
1987	4	204
1988	4	204
1989	4	204

All the artificial reefs are located within the coastal inshore waters and the majority are near the islands with distances ranging 200–500 meters from the shoreline.

2.2 Types of materials used

In the choosing of materials for construction of an artificial reef, consideration should be given to the following criteria:–

- they should be durable and long-lasting;
- they should be cheap and easily available;
- they should be easily handled and transported; and
- they should not leach out any toxic chemicals when immersed in seawater.

Discarded scrap tyres being cheap, readily available, easy to handle and transport have been found to be suitable for artificial reef construction. Tyres do not degrade in sea water nor leach out any toxic chemicals. On the other hand they provide substrate for attachment by encrusting organisms and also a new habitat for fish and other marine life. As a result, the majority of artificial reefs in Malaysia have been constructed with the use of discarded tyres.

The Department of Fisheries also embarked upon the construction of artificial reefs using derelict or confiscated fishing boats as reef materials in 1984 as their disposal posed a major environmental problem.

In 1986, the Department of Fisheries decided to establish artificial reefs using concrete pipes and culverts. The advantage of the concrete reefs is that they can be built bigger and stronger, and their design can be tailored to achieve optimum ecological effect on the marine environment.

2.3 Design and Construction

2.3.1 Tyre reefs

Tyres used for construction of artificial reefs were drilled or cut so as to let air escape during deployment. Two holes were cut into each tyre. Up to 1985, tyre reefs were constructed using 3–4 tyres tied up with polyethylene ropes. The tyres were tied to form a tetrahedral shape and transported in batches of 300–500 tyres to the artificial reef sites by fisheries research vessels or small fishing boats. These modules could be handled with ease during transportation and subsequent underwater reef construction. The modules of tyres were placed on the seabed by sliding them down a shot-rope tied to an existing reef to prevent the modules from drifting far apart. Research divers then tied these modules together with other adjoining modules to limit the possibility of any tyre module drifting loose. As a result the tyre reef was an irregular, haphazard bed of tyres with height not exceeding one meter.

Under the accelerated programe of reef development in 1986, tyres are tied into a pyramid using a total of 42 tyres with a resultant height of about 2 meters (Fig. 2). The floor space occupied by a single pyramid is about $3m^2$. A large polyethylene rope, diameter of about 20 mm is then threaded through the tyre pyramids before they are sunk at a reef site. Subsequent expansion involves a procedure whereby the pyramids are allowed to slide down a shot-rope tied to an existing reef and the shot-rope is then tied to the last tyre pyramid (for that launching) before being sunk onto the seabed. The tyre pyramids are randomly spaced on the seabed with occasional piling of a few pyramids reaching a height of 3 metres or more. Due to this loose arrangement, an artificial reef of 50,000 tyres can cover a seabed area of 0.7 hectares.

2.3.2 Boat reefs

Prior to deployment at a reef site, derelict or confiscated boats were cleared of all debris and loose pieces which would otherwise result in flotsam upon sinking of the boat. All water tanks and fuel tanks were opened or punctured to prevent trapped air hindering the sinking of the boat. At the artificial reef site, the boats were anchored and then sunk by allowing water into the boat by knocking out the propeller shaft or by opening sea-cocks. In the case of smaller boats, an axe was used to knock out holes in the hull.

2.3.3 Concrete reefs

The first concrete reef was built at Pulau Payar, Kedah in December 1986. The two types of reef deployed then were of :–

a) concrete drainage culverts (0.6 m in length × 0.6 m in height)

b) concrete pipes (0.6 m in length × 0.6 m in diameter)

A pyramidal configuration was attained by arranging 20 concrete units on a wooden platform of "Chengal" hardwood and secured by steel cables (Fig. 3a & 3b). The resulting structure was 1.2m in length, 2.4 metres in width and had a height of 2.4 metres. Ten units of each type of concrete reef, were individually placed on the seabed with the use of a crane.

In December 1987, another 20 units of concrete pyramids were deployed at P. Payar to expand the existing artificial reef there. Modifications were made to increase the size of these concrete pipe units to 1.8 m long, and 0.9 m in diameter. The thickness of the concrete pipe was increased from 3.8 cm to 5 cm and strengthened with BRC–10 specification. The concrete pipe itself had 8 holes of 20 cm diameter and the wooden platform had 4 cross-beams instead of the 3 cross-beams (previous design). The diameter of the steel cables was increased from 7 mm to 10 mm and a total of 4 such steel cables were used instead of only 2 steel cables per pyramid in the previous design. The resulting structure was about 1.8 m wide, 3.65 m in length and 3.6 m in height (Fig. 4). Twenty units of concrete reefs of the same design were also deployed at a new site off Muka Head, Penang in December 1987.

As in the initial launching in December 1986 at Pulau Payar, a barge equipped with a crane had to be used for transportation and deployment of the concrete pyramids at the artificial reef site. However a simple system of loops was devised to allow the release of the crane's cable from the surface thus eliminating the need for divers to go under water to unshackle the cable (as in the initial launching at P. Paya in December 1986) after each and every emplacement of the concrete pyramids.

A total of 144 concrete pyramids was also used earlier for the establishment of two concrete reefs off Kuala Ibai and Kuala Setiu, Terengganu in November 1987. However due to a combination of factors – rough sea conditions, lifting capacity of crane and the weight of concrete pyramid only 6 concrete pipes were used per unit of concrete pyramid (Fig. 5). Each concrete pipe was 1.8 m in length and 2.7 m in diameter.

2.4 Financial support

Under the National Agriculture Policy (NAP) formulated in 1984, the Government of Malaysia has accorded high priority to the fisheries sector with special emphasis on (i) intensification of rehabilitation, conservation and protection of coastal fisheries resources; (ii) improvement of fisheries support services particularly in the fields of research and development, training and extension; and (iii) maximizing export earnings through offhore fisheries.

Accordingly, under the budgeting category of fisheries management and conservation, the Fifth Malaysia Plan (1986–1990) has allocated a budget of M$8.24 million for the development of artificial reefs towards fisheries resource enhancement.

2.5 Duration of Programme

The artificial reef development programme is scheduled to utilize about 1.5 million tyres in the construction of all 65 artificial reefs of tyres in Malaysia by the end of the Fifth Malaysia Plan (1986–1990). Each artificial reef will comprise an average of 28,000 to 50,000 tyres and an expected 1.5 million tyres will be needed for the completion of all 65 tyre reefs by the end of 1990.

3. CRITERIA FOR SITE SELECTION

The selection of sites for the establishment of artificial reef is based on the following criteria:–

(i) firm seabed - a sandy bottom is preferable

(ii) depth range between 15 m to 25 m

(iii) adequate water clarity

(iv) absence of strong currents

(v) situated away from traditional fishing grounds

(vi) guaranteed navigational safety

4. MAINTENANCE, OPERATION AND MONITORING

4.1 Organizational aspects

With the formulation of the comprehensive programme of artificial reef construction and development under the Fifth Malaysia Plan, a coordination committee was set up in 1986 to ensure the smooth running of the project. Staff from the Fisheries Research Institute, the State Fisheries Offices and Department of Fisheries Headquarters comprise the Coordination Committee. Subsequently, a Coordination Secretariat was set up by the Department of Fisheries Headquarters for the overall supervision and coordination of the artificial reef programme at all stages particularly in the provision of funds/financial allocation and the formulation of policy for artificial reef management and development. A work-flow chart showing the responsibilities of the participating sections/staff is detailed in Table 4.

Table 4. Work-flow chart for establishment of artificial reefs.

STAGE 1	STAGE 2	STAGE 3
Fisheries Research Institute (Conservation Unit)		
– Proposal of sites	– Site surveys and selection	– Monitoring of artificial reefs
– Reef design (with Technical Sect'n of DOF, HQ)	– Assist in a–reef construction	– Planning for a–reef expansion
State Fisheries officies		
– Storage of tyres	– Arrangement of contracts	– Expansion of a–reef with FRI as adviser
– Cost-estimate of contract to private sector	– Supervision in preparation launching and expansion	– Enforcement of regulations to prohibit fishing at a–reef sites
	– Deployment of marker bouys	
Coordination Secretariat, DOF HQ		
– Provision of funds	– Supervision and coordination of the a–reef programme at all stages	– Distribution of tyres for expansion
		– Policy making for management of artificial reefs
– Collection and distribution of tyres		and preparation of, annual artificial reef report.

4.2 Results on Fishery Production

Qualitative surveys were conducted by divers from the Fisheries Research Institute, from time to time. Preliminary observations at some of the reef sites showed that the artificial reefs were rapidly colonized by fish in the first few months after deployment. The rate of recruitment leveled off after about one year. At the Pulau Payar tyre reef in Kedah, the fish population has reached a stable state (A.R. Latun and M.K. Rajuddin, 1989) showing the rise and fall in fish population.

Encrustation on the surface of the artificial reef, be it tyres or concrete, was prolific with a wide variety of organisms such as micro-algae, sponges, tunicates, anemones, hard corals and bivalve molluscs. The rate of encrustation appeared to be faster on the concrete reefs than on the tyre reefs.

The major species of fish identified in the artificial reef sites are snappers, groupers, fusiliers, sweetlips, parrotfishes, rabbitfishes, jacks and damselfishes. Large shoals of snappers, *Lutianus* sp. numbering about 10000–15000 and fusillers, *Caesio* sp. numbering about 10000 are not uncommon.

At the concrete and tyre reefs in Pulau Payar, Kedah, large shoals of Carangids can be observed occasionally swimming in between the artificial reefs. Groupers are also attracted to the reef. Census at some reef sites indicates a population level of 1 grouper per 10 m^2. The grouper population differs between artificial reef sites; certain small reef sites harbour as many as 30–40 groupers within the artificial reef.

4.3 Assessment of Impact

4.3.1 Socio-economic

A socio-economic analysis of the artificial reef development programme in Malaysia has yet to be conducted. Studies in the United States of America have suggested that artificial reefs had a positive effect on the economy of the nearby communities (Buchanan 1973). Informal interviews with local fishing communities indicated their enthusiastic support and appreciation of the artificial reef development programme. There are many requests from Fishermen Associations concerning the deployment of artificial reefs in their areas.

4.3.2 Fisheries

In spite of the prohibition of fishing at artificial reef sites, local fishermen have reported encouraging catches of market-value species such as groupers and snappers using traps and handlines e.g. handlining with a single hook could yield 5 kg per hour of snappers at the concrete reef in Kuala Setiu, Terengganu.

5. PROBLEMS AND CONSTRAINTS – MANAGEMENT ASPECTS

Under the accelerated programme of reef development, a total of 1.5 million tyres will be collected and emplaced at all the artificial reef sites by 1990. This has posed severe logistical problems in obtaining supply, storage, transportation and preparation of the tyres. By the month of August 1989 over 1 million tyres had been emplaced at artificial reef sites.

Many studies have been carried out world-wide, Bohnsack and Sutherland (1985) reviewed artificial reef literature and found numerous, well-documented observations of rapid colonization rate, high fish densities and high catch rates at arrificial reef sites. However, the majority of these studies have qualitatively described species succession and ecological developments and high priority should now be given to test predictive models quantitatively to determine causes of phenomena associated with artificial reef (Bohnsack 1985). A monitoring programme is needed to quantify the benefits of

deploying the artificial reefs. Artificial reefs that act primarily by attraction may promote overfishing under heavy fishing pressure by increasing fish catchability.

Governed by the objectives behind the development of artificial reefs in Malaysia, the Department of Fisheries has imposed prohibitions against fishing at artificial reef sites up to a radius of 0.5 nautical mile. The rationale for artificial reef development is the hypothesis that artificial reefs provide additional critical habitat that increases the environmental carrying capacity and eventually the abundance and biomass of fishes. Fisheries resources and other marine life in the immediate vicinity of the artificial reefs must be protected and conserved in order that the artificial reefs can fully realize their potential in habitat rehabilitation and resource enhancement of the coastal waters.

6. RECOMMENDATION FOR FUTURE PROGRAMME

Up till now, the amount of time put into the monitoring of arrificial reefs is minimal compared with the effort put into their establishment. Due to time constraints, most of the reefs were deployed without any proper baseline study. The absence of baseline studies makes it difficult to evaluate their performance. Understanding the extent to which they attract or increase fish biomass is important for wise fishery management and effective construction and deployment of artificial reefs.

In future, an artificial reef monitoring programme should be established to quantify the benefits in terms of fisheries resources enhancement, conservation and rehabilitation of coastal ecosystems. The socio-economic impact of the artificial reef project on the artisanal fishermen should also be considered. Pending the outcome of such monitoring studies, the artificial reefs programme may be reviewed so as to expand the size of each existing reef or to increase the number of such reefs in our waters.

Accordingly, the Department of Fisheries has embarked on experiments with materials other than tyres for construction of artificial reefs. The PVC ultralight reef deployed in February 1990 at Pulau Lembu, Kedah will be tested for its effectiveness in aggregating fishes and forming a new habitat. It is still early to know the outcome of this experiment. Other materials will also be tested.

The Department of Fisheries has also decided to embark upon a supplementary restocking programme whereby selected high-value species will be released within the artificial reef area. The restocking programme is expected to increase the fish population of selected high-value species such as groupers, seabass and snappers.

Appropriate management strategies should be adopted so that artificial reefs can produce significant new biomass thus increasing fishery resources. Poor management strategies whereby artificial reefs are used merely to aggregate fish, thereby increasing the catchability of such fish can cause overfishing. Maximising the potential of artificial reefs for habitat and resource enhancement is critical especially when signs of overfishing occur.

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FIG.1a

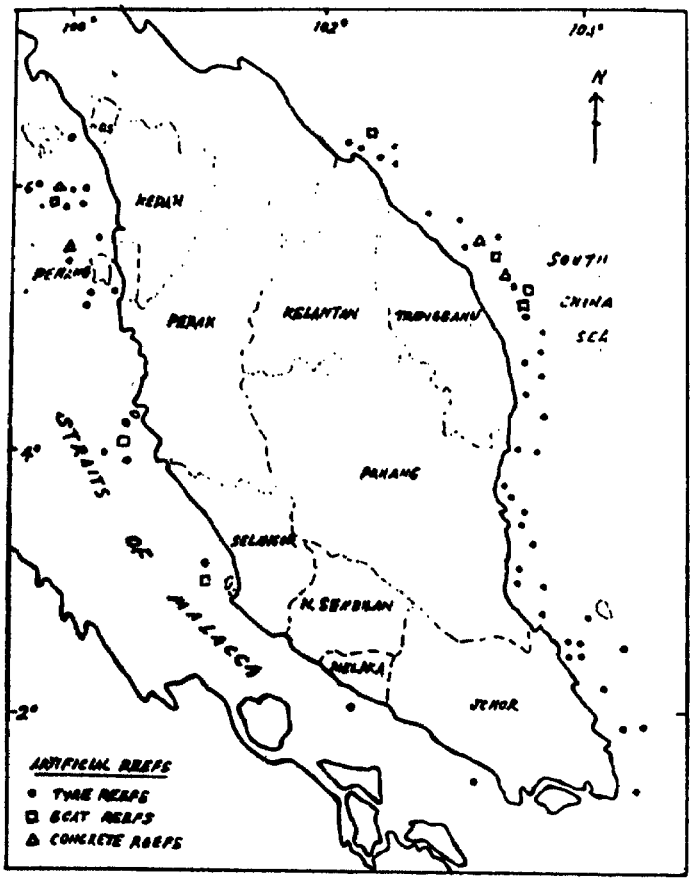

Figure 1a. Location of artificial reefs in Peninsular Malaysia.

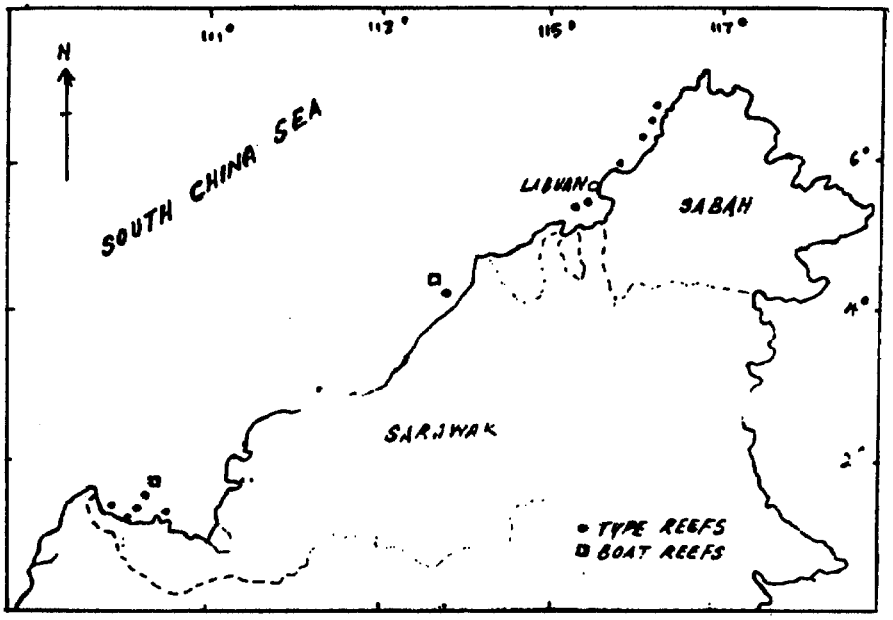

Figure 1b. Location artificial reefs in East Malaysia (Sabah/Sarawak).

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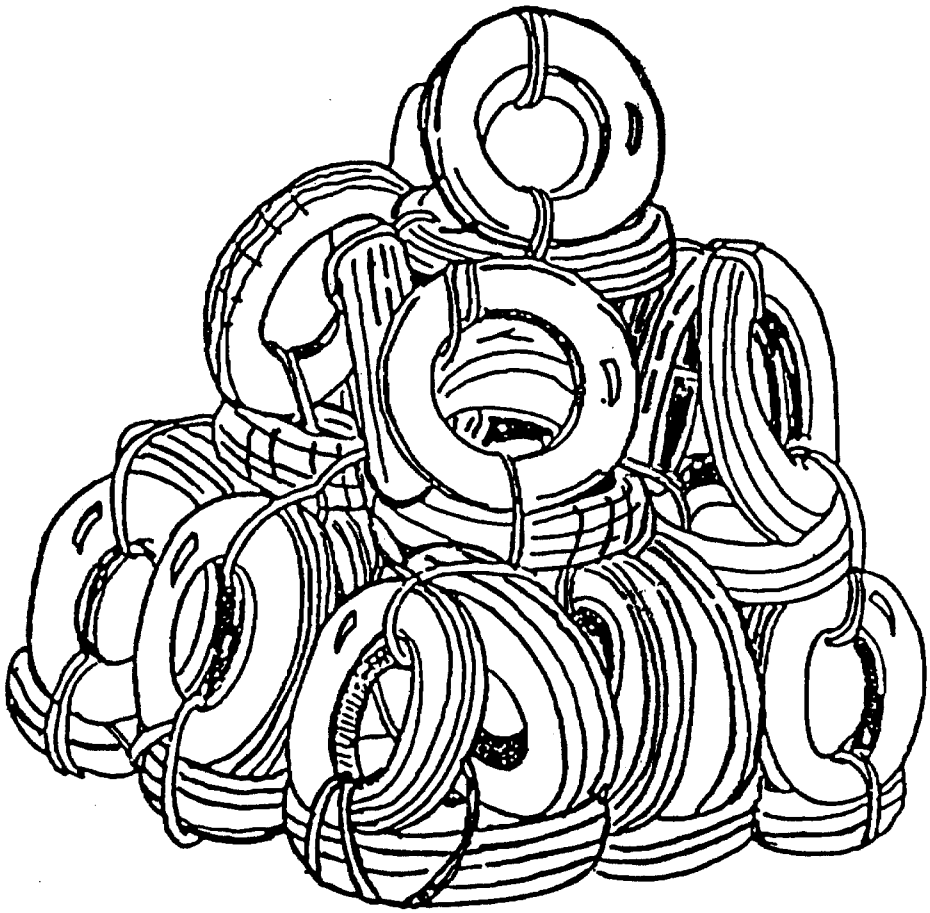


Figure 2. Tyre pyramid.

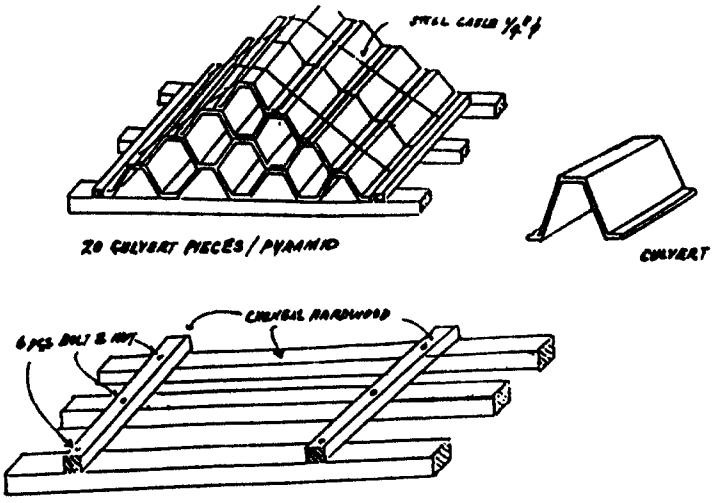


Figure 3a. Concrete pyramid (culvert).

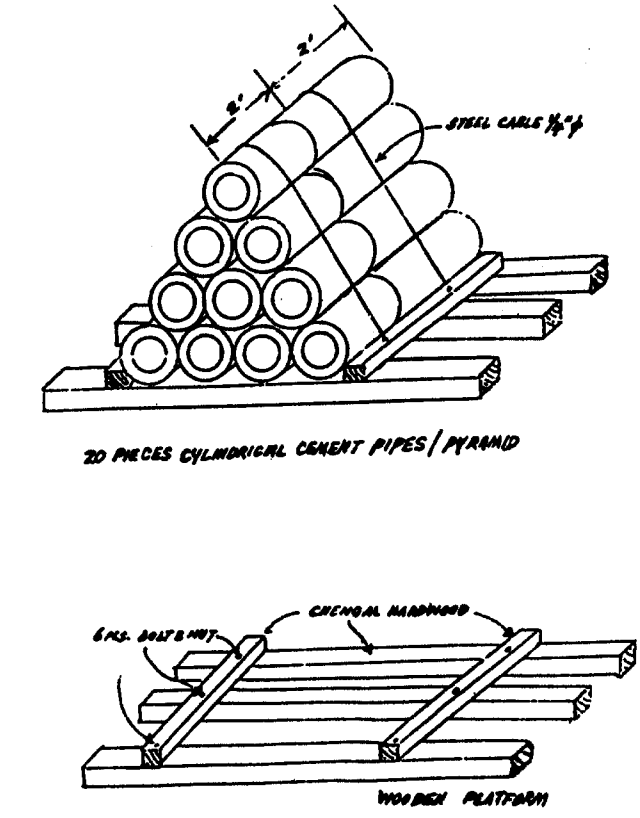
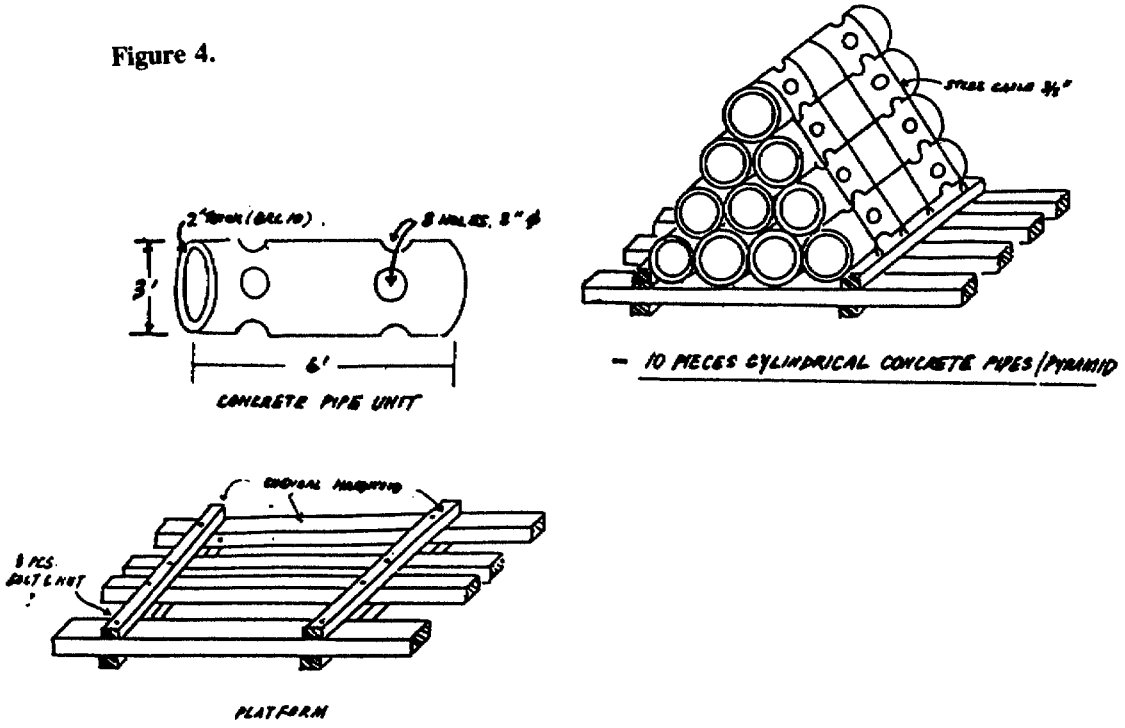


Figure 3b. Concrete pyramid (pipes).

Figure 4.



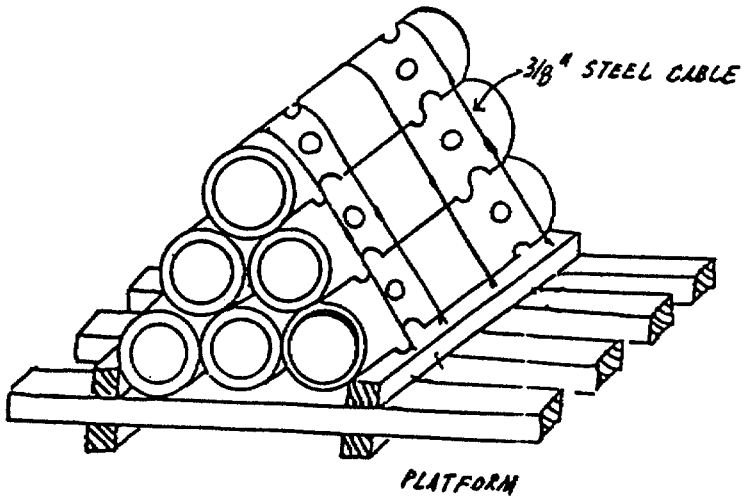


Figure 5. 6 pieces cylindrical concrete pipes/pyramid.