Technical Note N-1124

ANIMAL UNDERMINING OF NAVAL SEAFLOOR INSTALLATIONS

By

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YF 38.535.002.01.011

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ABSTRACT

In-situ foundation performance experiments are being conducted by Naval Civil Engineering Laboratory (NCEL) ocean engineers by placing 4-foot diameter cylindrical concrete footings for undersea structures on the ocean floor in 120 feet of water. During periodic monitoring of footing performance, excessive settlement was noted and the resulting inspection of the footings by divers showed several animal burrows under the footings. As a result of this finding, a field study was initiated to investigate and to identify burrowing animals which may undermine the footings of Navy undersea structures. A control method which will prevent animals from burrowing underneath objects placed on the ocean bottoms was investigated. A limited literature search was also conducted to determine what type of burrowing animals may be present in the vicinity of the Pitas Point Test site.

INTRODUCTION

Information on engineering properties of bottom sediments is essential for (1) determining their effects on proposed foundations for undersea structures, (2) selection of suitable sites, and (3) designing a foundation (footings) for underwater Navy structures. To obtain such information, an in-situ footing foundation performance experiment was initiated by Naval Civil Engineering Laboratory (NCEL) engineers by placing several 4-foot diameter by 2-foot high cylindrical concrete footings (Figure 1) on the seafloor in 120 feet of water at Pitas Point, located about 12 miles north of Port Hueneme, California.[1,2] The seafloor at this test site consists of fine clayey-silty sediment. The inspection of the emplaced concrete footings was conducted regularly by Navy Seabee divers.[3] After several weeks of exposure on the seafloor, divers, prompted by observations of unusually large settlements, discovered several individual tunnel-like openings of animal burrows measuring 2 to 3 inches in diameter located around the perimeter of the footings. This finding was of great concern to ocean engineers because such animal burrows may undermine the stability of the concrete footings placed on the seafloor.

A work unit, YF 38.535.002.01.001, "Animal Undermining of Naval Seafloor Installations", was assigned and work was initiated in FY70 to investigate and identify marine animals responsible for undermining the seafloor installations and to formulate an effective control method which will prevent animals from burrowing underneath the footings. A limited literature search was also conducted to determine (1) what type of burrowing animals inhabit the bottom sediment in the vicinity of Pitas Point, (2) the distribution of significant burrowing animals found at Pitas Point, and (3) what type of marine animals will burrow or excavate a hole under objects placed on the ocean floor which may affect the stability of the military seafloor structures.

MATERIALS AND METHODS

Inspection of the 4-foot diameter cylindrical concrete footings and collection of burrowing animals found in the vicinity of these footings were conducted by Navy Seabee divers. The divers were limited to 15 minutes of work which included time of descent, inspection of footings, and any other work to be done. In that particular location (Pitas Point), visibility on the ocean floor was often poor (practically zero) because

of the presence of fine clayey-silt suspended in seawater. For this reason, the divers were handicapped in making visual observations and often had to rely on the sense of touch to examine the footings. After surfacing and coming aboard the ship, each diver reported his observations, findings and work conducted at the ocean bottom.

Because the 4-foot diameter cylindrical concrete footings were too heavy to be moved by divers in the event burrowing animals are found beneath these footings, four lighter and smaller aluminum footings (1/2 x 24 x 24 inch) and four concrete footings (1-1/2 x 24 x 24 inch), were made (Figure 2). These simulated footings, with handles, were made light enough for a diver to lift and move the footing while a second diver uses a biological dredge to collect bottom sediment which may contain some burrowing animals.

A 6-inch wide by 1/8-inch thick aluminum sheet was placed around two of the 2-foot square aluminum plates (forming a skirt) and also around 2 of the concrete blocks (Figure 3). These were placed on the ocean floor at Pitas Point in the form of inverted box. The 6-inch wide sheet buried deep in the soft sediment was to serve as a mechanical barrier against animals burrowing just below the sediment-water interface. To prevent rapid corrosion, a protective coating of white vinyl paint was applied over the surface of the aluminum after it was treated with a pretreatment primer, Formula 117.

As a chemical means of preventing animals from undermining the footings, about 25 grams of copper sulfate crystals were placed in a plastic bag (sealed) and secured by wires to the underside of aluminum footings, one with and one without skirts, and to a concrete simulated footing with skirts. On the seafloor the sealed plastic bag with the copper sulfate was punctured with a diver's knife to dissolve the crystals and to saturate the sediment with the chemical under the footing. It was anticipated that such a chemical treatment would rout animals living in the sediment. The various simulated footings were placed in sets adjacent to a 4-foot diameter footing and were secured to it with a plastic rope so that the smaller flat footings could be located quickly by divers. The footings were inspected periodically by divers for burrowing animals and other environmental effects on the footings.

In April 1970 two additional concrete simulated footings (without skirts) were placed on the seafloor in 120 feet of water about four miles southwest of Port Hueneme Harbor. The footings were placed near a Submersible Test Unit (STU) that is currently being used for the study of biodeterioration and fouling of materials. The two footings were exposed at this particular test site because the visibility on the seafloor there is normally very good (up to about 15 feet), and any undermining of the footings caused by marine animals can be inspected visually. The bottom sediment is composed of fine silty sand.

In order to collect burrowing animals from underneath the simulated footings, two biological dredges with cover (one 8 x 12 x 18 inches and the other 8 x 18 x 18 inches in dimension) were fabricated (Figure 4). Burrowing animals found in the bottom sediment were washed and preserved in 10% formalin solution for later classification in the laboratory.

RESULTS AND DISCUSSION

Pitas Point Test Site

An average of about one inspection dive per month was conducted to inspect and evaluate the various footings placed on the seafloor at Pitas Point. Divers have discovered deep scoured areas underneath one side of the 4-foot diameter concrete spread-footings. Because of poor visibility encountered on the seafloor, animals which could have been inhabiting the scoured area under the footings were not detected. Animals actually tunneling or scouring the sediment under the footings were also not detected nor observed by divers. An NCEL engineer-diver who inspected the 4-foot diameter footings observed that the scouring effects were found on one side of each of the three footings and that one of these footings had fallen into the scoured depressions. As a result of this observation, it was tentatively concluded that surge action caused by large swells may have been responsible for the scouring effect produced under the footings rather than by marine animals. However, there are marine animals which do scour or excavate a depression under rocks or other objects placed on the seafloor. The California spiny lobsters have been observed by divers to scour a deep hole under rocks as a place to hide from predators.[4] Hartman[5] mentions that there is a burrowing fish, *Otophidium sp.* which inhabits the ocean floor. It is an eel-like fish commonly known as a spotted cusk-eel[6] which ranges from Oregon to Baja California living on the seafloor in depths of 60 to 800 feet or more. The adult cusk-eel is about 14 inches long and burrows rapidly into the sediment tail first when startled or disturbed. The adults are usually found hidden beneath rubbles and crevices and holes on the sea floor.

During one dive in March, the visibility was exceptionally good (up to 2 feet) at the bottom and divers reported observing fish (*Sebastodes paucispinis*) up to 2 feet in length and large crabs (*Cancer sp.*) inhabiting the scoured depressions under the footings. The animals seem to have been keeping the scoured areas underneath the footing clean and from becoming refilled with silt. These animals could enlarge the holes under the footing. Divers also reported numerous animal mounds on the seafloor with about a 2-inch diameter tunnel-like opening in the center of the mound. These mounds were located in the vicinity of the spread-footings. These could be the burrows of *Listriolobus pelodes*, an echiuroid worm, reported by Barnard and Hartman.[7] These authors have conducted studies on the kinds, numbers, sizes, and quantitative distribution of the benthic animals of the Santa Barbara shelf which includes areas around Pitas Point. They have found that the silt bottom is dominated by *Listriolobus pelodes*. The individual worms form U-shaped burrows with two partially plugged surface openings as much as three to four feet apart; and the burrows extending as much as three feet below the surface. The greatest concentration was found to occur along the 20 fathom contour along the coast of Santa Barbara to a point east of Pitas Point. Along this contour the individuals are reported to number about 100 to the square meter, and have a biomass of about 1,100 grams to the square meter.

The finding of several individual 2-inch diameter tunnel-like holes in the sediment around the perimeter of a concrete footing at Pitas Point test site during the early part of the foundation experiment (mentioned under INTRODUCTION) could have been the burrows of *Listriolobus pelodes*. If this is so, this particular burrowing animal would be of interest to an ocean engineer because when undersea structural foundation is placed over such animal burrows, these may affect the stability of the foundation by causing rapid settling and possibly tilting.

Simulated Footings. The simulated footings were inspected periodically by divers for signs of animal burrows under and around the perimeter of the 2-foot square footings. Because of very poor visibility encountered on the seafloor, the inspections were performed primarily by feeling along the edges of the footings by hand rather than visually for signs of animal burrows. The divers did not see or feel any animal burrows under or around both the non-skirted and the skirted footings. However, the divers did note that one side of the footings was scoured exposing the concrete surface and the 6-inch wide aluminum barrier plate. On the opposite side of the scoured area, there was a slight build-up of sediment over the footings. Since the deep scouring effect was present on one side of the footings, it was tentatively concluded that the surge action at the ocean bottom may have caused such an effect. Because of poor visibility, the divers did not detect any marine animals swimming or crawling out of the scoured depression in the bottom sediment.

After about 8 months of exposure on the seafloor, the sediment from underneath the 2-foot square simulated footings was collected and examined for burrowing animals. Two divers who were sent to the bottom to collect the sediment from under the 2-foot square footings could not break out the footings, which by this time, were buried in the soft sediment. The footings were released (singularly) from the sediment by pulling on a rope connected to the handle of the footing from aboard ship. As soon as the footing was loosened from the sediment, a signal was received from the divers on the seafloor to stop and slacken the rope. Of the 8 footings which were emplaced on the seafloor, all 4 of the concrete footings were recovered. One of the aluminum footings was found caught under one of the heavy 4-foot diameter cylindrical footings that had been lifted and moved during an experimental manipulation. Divers reported that the large concrete footing was sitting directly on top of the handles of the simulated footing and that about 3/4 of the area under the 4-foot diameter footing was scoured (4 to 5 inches deep). The other aluminum footings were lost, probably buried in the soft sediment, because a concrete footing to which they were connected was found broken (Figure 5).

The sediment from under the following four 2-foot square footings, located by divers, were collected and examined for burrowing animals:

1. Concrete Footing (Figure 6). There were 10 *Listriolobus pelodes* and over 25 *Stemaspis sp*, an annelid worm, in approximately one

cubic foot of sediment collected from under the footing (Figures 7 and 8). Barnacles were not found attached to the surface of this concrete footing probably because it was buried and covered with about 2 inches of bottom sediment when located.

2. Concrete Footing (broken). There were 5 small *Listriolobus pelodes* and about 10 *Sternaspis sp.* in the sediment sample.

3. Concrete Footing with Aluminum Skirt (Figure 9). Burrowing animals were not found in the sediment sample. The mud sample collected by divers from underneath the inverted box-like structure was black and a strong odor of hydrogen sulfide (produced by sulfate-reducing bacteria) was being given off from the sediment. This indicates that an anaerobic environment was formed in the sediment under the footing and that such environment prevented burrowing organisms from undermining the footing. Numerous barnacles (*Balanus concavus pacificus*) were attached to the surface of the concrete and paint but upon closer examination all the animals were found to be dead (Figure 10). There were numerous large blisters formed under the vinyl paint where the painted section had been exposed in mud containing black sulfides.

4. Copper Sulfate Placed Under Concrete Footing with Aluminum Skirt (Figures 11 and 12). Only 3 *Sternaspis sp*, an annelid worm, were found in the sediment sample. Specimens of *Listriolobus pelodes* were absent. A small sample of sediment found inside the protected footing was slightly discolored and produced a trace of hydrogen sulfide odor. For this reason, the environment under the footing was slightly anaerobic.

From all indications, the 6-inch wide mechanical barrier placed around the footings produced an anaerobic environment in the sediment by preventing fresh seawater from entering the protected area. Such an environment will prevent most marine animals from undermining the footing. Copper sulfate crystals placed under flat footings may rout animals living in the sediment but they may return after the copper sulfate has been depleted and washed away.

In addition to *Listriolobus pelodes* and *Sternaspis sp.* collected from underneath the simulated footings, divers have collected the following animals living in the sediment in the vicinity of the footings: *Glycera sp*, a segmented worm about 8 inches long (Figure 13), *Pagurus hirsutiusculus*, a hermit crab which was living in an empty shell of a moon snail (Figure 14); Cancer crab (Figure 15) and Sea-pens. The following marine organisms were found attached to recovered test materials (instruments, plastics, wood) which were exposed on the seafloor in 120 feet of water; barnacles, (*Balanus concavus pacificus)*, hydroids, bryozoan, and molluscan wood borers *(Bankia* and *Teredo)*.

STU Test Site

After about two months of exposure on the ocean floor the two 2-foot square concrete footings, separated about three feet from each other, were inspected for animal undermining. Divers reported that the visibility on the seafloor was excellent and that they found deeply scoured areas underneath both footings. The scoured area measured about four inches deep into the sediment below the footings and about six inches wide from the edge toward the center of the footing. The scouring effect was present on different sides of the two footings (Figure 16), so that it appeared doubtful that bottom currents would have caused it; animals may well have been responsible. At the time of the inspection, however, animals were not found close to nor detected inside the scoured area under the footings.

Burrowing Animals

Glycera sp, an 8-inch long segmented worm, (Figure 13), found in bottom sediment at Pitas Point has also been found in other localities such as in Los Angeles - Long Beach Outer Harbor, Palos Verdes shelf and slope, San Pedro shelf and around Catalina Island. *Glycera* is remarkably well adapted for quick burrowing. It inserts the pointed head into the sediment, and as the body is rotated, it penetrates the fine silty bottom with such speed as to disappear instantly. Another marine animal, the moon shell *Polinices* (about 3 inches in diameter), found at Pitas Point is known to burrow about 12 inches deep into the sediment.[10]

Barnard and Hartman[7] using an orange-peel grab to collect bottom sediment have found numerous varieties of animals inhabiting the fine clayey-silt sediment along the Santa Barbara shelf and around Pitas Point. These animals in decreasing order of frequency are presented in Table I.

Other burrowing animals, besides *Listriolobus pelodes*, which may be of interest to ocean engineers are various species of clams which live in the bottom sediment along the coastal shores from California to Washington. These include:

Panope generosa, a geoduct, is a large clam found along the coast. Individuals with shells more than 8 inches long are not uncommon. The clam lives in a semipermanent burrow that is often 3 feet below the surface sending its immense siphons up to the surface.

Schizothaerus nuttallii, or gaper clam, also lie from 1-1/2 to 3 feet below the surface and range from San Diego to Alaska. Other varieties of clams which live in deep burrows are: *Saxidomus nuttallii*, *S. giganteus*, *Mya arenaria*, and *Macoma nasuta*.

Marine worms which build large elongated burrows on the ocean bottom include *Urechis caupo*, an echiuroid worm, which forms U-shaped burrows with entrances from 16 to 38 inches apart. The animal itself is about 8 inches long, but some may grow up to 20 inches long. These worms are known to be present in Newport, Morro, San Francisco, and Humbolt Bays. Another worm similar in habit to *Urechis* is *Ochetostoma octomyotum*. *Chaetopterus variopedatus*, a segmented worm, which grows from 6 to 15 inches long, lives in a U-shaped burrow, the tube may be several feet long.[11]

CONCLUSIONS

There are various burrowing animals inhabiting the seafloor. Designers of foundations for seafloor structures should consider possible problems that might arise as a result of animal burrows; a mechanical barrier may alleviate such problems.

Table I. Benthic Animals Found Along the Santa Barbara Shelf[7]

Listriolobus pelodes	echiuroid worm
Phoronopsis sp	phoronid worm
Callianassa sp	shrimp
Ceratocephala crosslandi americana	segmented worm
Marphysa sp	segmented worm
Pectinaria californiensis	segmented worm
Hesperonoe sp	segmented worm
Sternaspis fossor	segmented worm
Pinnixa	crab
Amphiodia urtica	brittle star
Saxicavella pacifica	clam
Compsomyax	clam
Glycera americana	segmented worm
Glycera capitata	segmented worm
Asychis lacera	segmented worm
Cerianthid anemone	coelenterate
Stylatula sp	coelenterate
Pista disjuncta	segmented worm

Figure 1. A 4-foot diameter by 2-foot high cylindrical concrete footing.

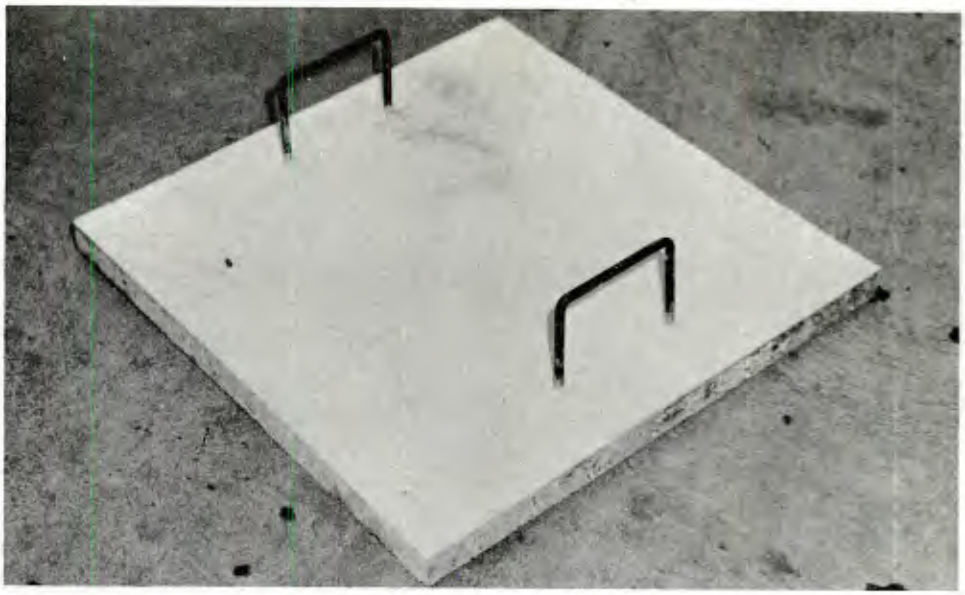

Figure 2. A 1-1/2 x 24 x 24 inch concrete test block with handles, before exposure in the sea.

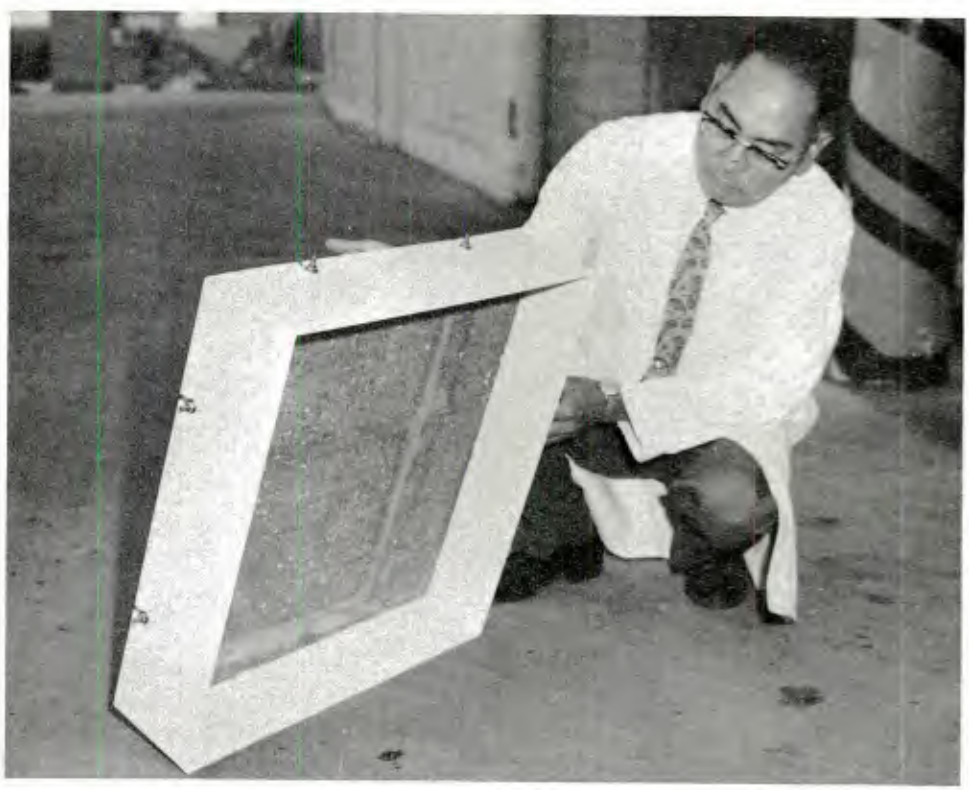

Figure 3. A 1-1/2 x 24 x 24 inch concrete test block with 6 inch wide painted aluminum sheet to serve as a mechanical barrier against burrowing animas, before exposure in the sea.

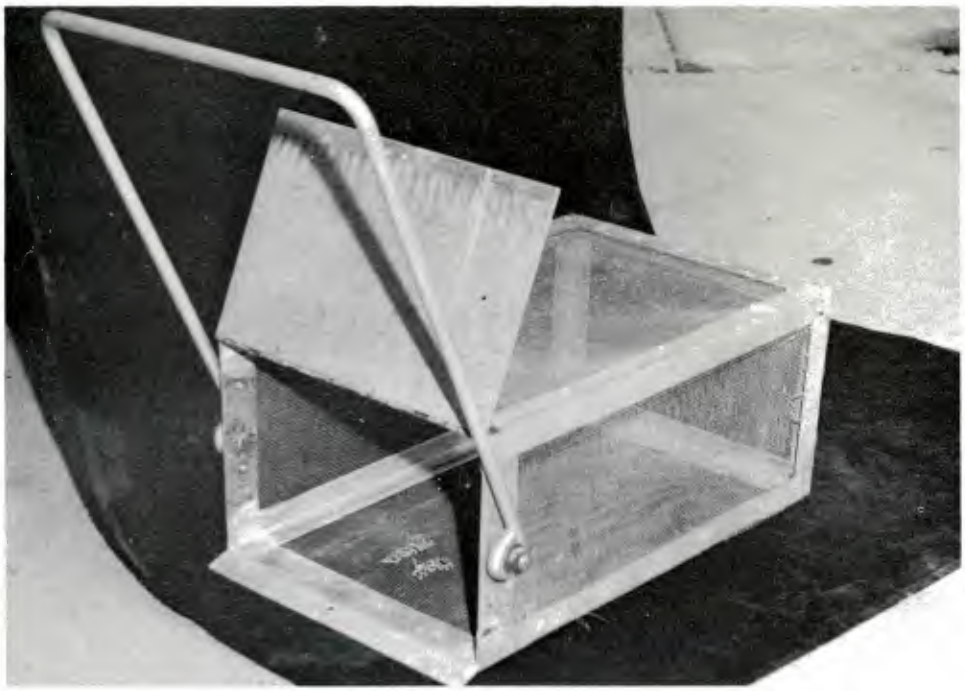

Figure 4. A biological dredge with cover.

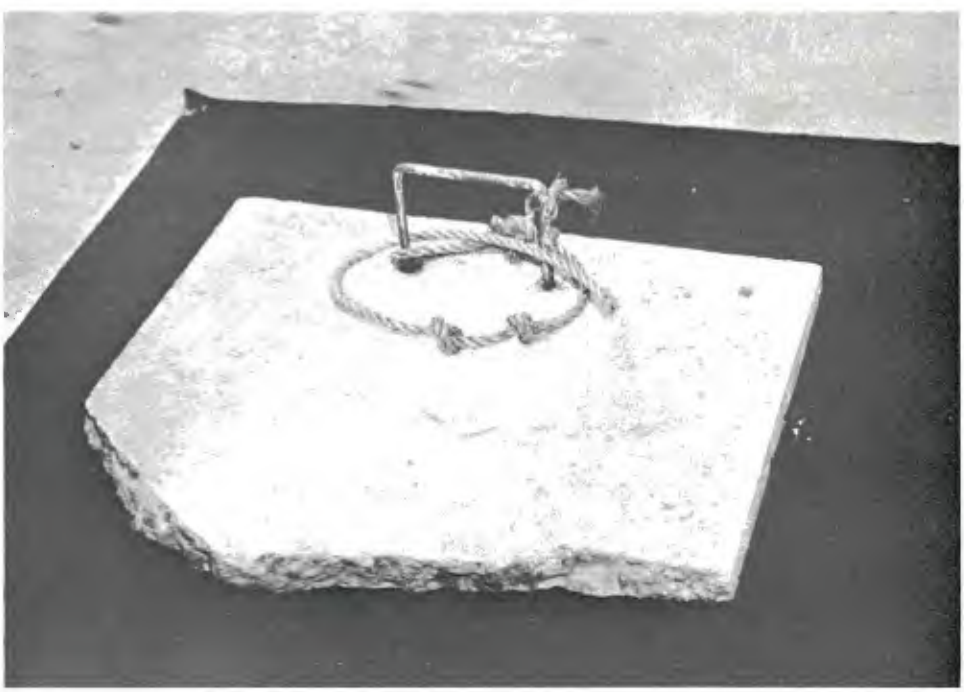

Figure 5. Broken 2-foot square concrete footing recovered from the seafloor.

Figure 6. Recovered 2-foot square concrete footing.

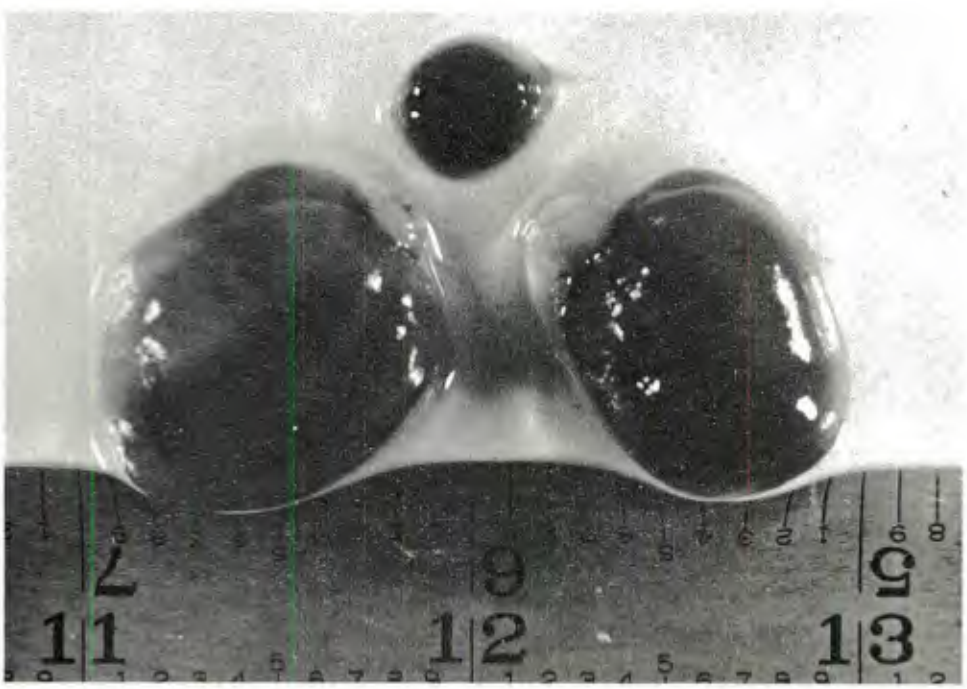

Figure 7. *Listriolobus pelodes*, an echiuroid worm, which forms a U-shaped burrow in the sediment.

Figure 8. *Sternaspis sp*, an annelid worm.

Figure 9. Interior view of recovered concrete footing with aluminum skirt.

Figure 10. Shells of dead barnacles (*Balanus concavus pacificus*) attached to the surface of concrete and paint.

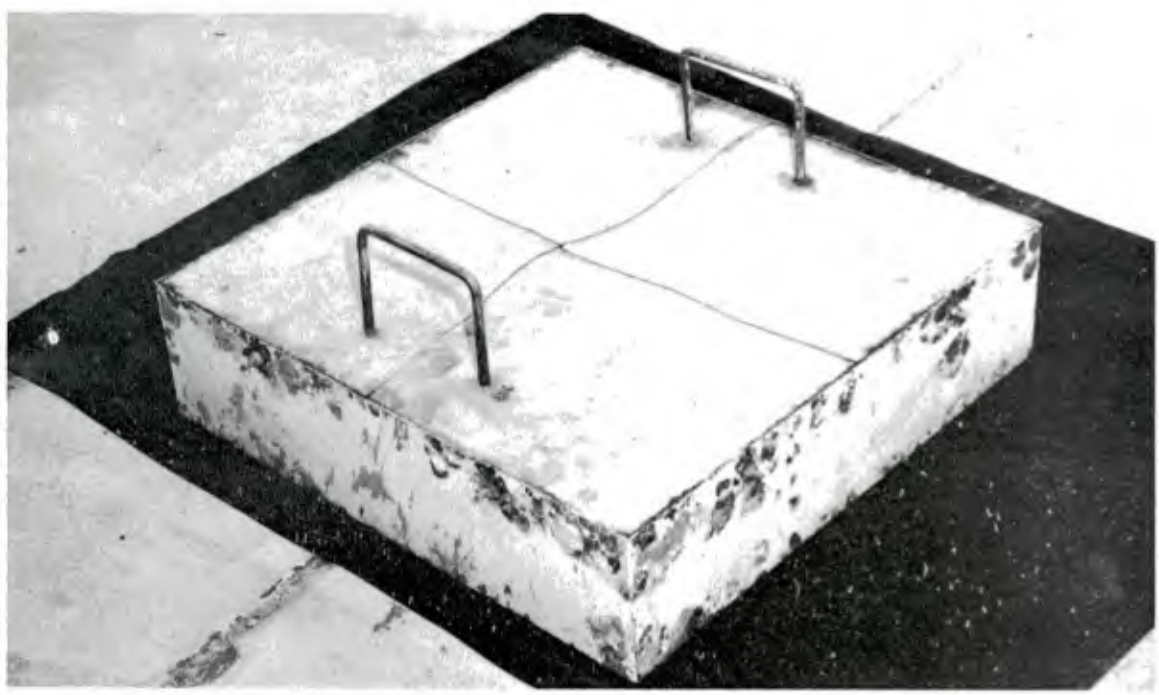

Figure 11. Exterior view of recovered 2-foot square concrete footing with an aluminum skirt.

Figure 12. Interior view of Figure 11 showing plastic bag which contained copper sulfate crystals.

Figure 13. *Glycera sp*, a segmented worm, about 8 inches long which lives in soft sediment.

Figure 14. A large hermit crab living inside a moon shell.

Figure 15. A large Cancer crab with barnacles growing on its carapace.

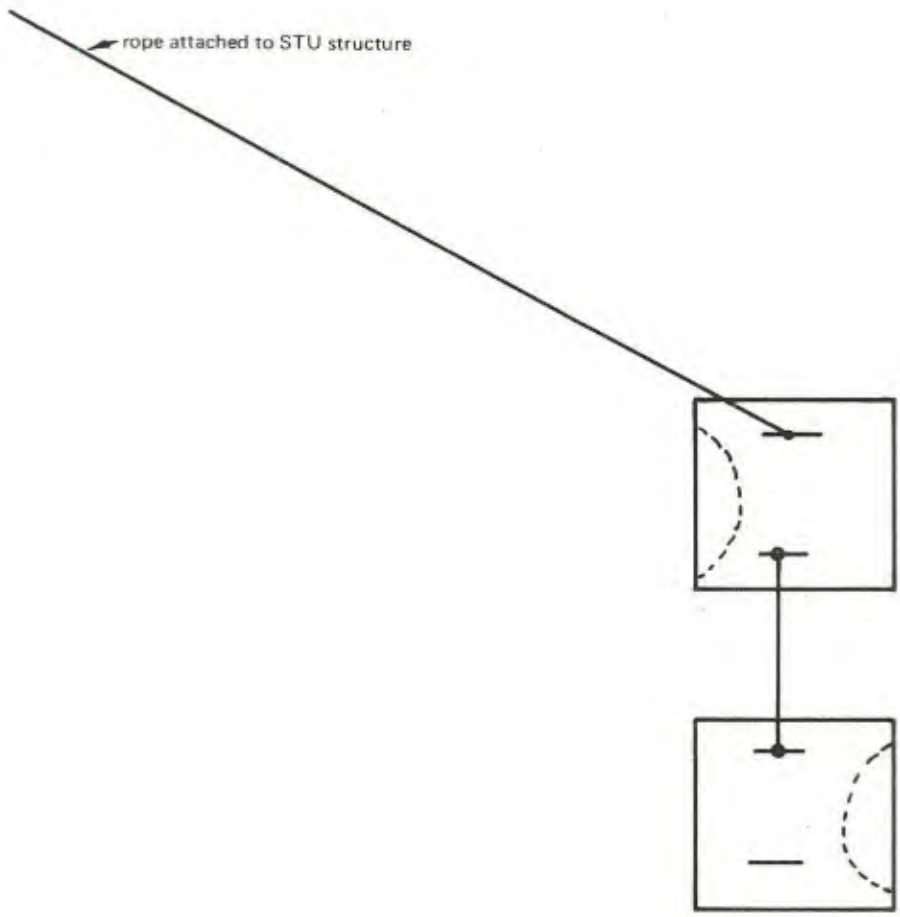

Figure 16. Scouring found under the 2-foot square concrete footings exposed on the seafloor at STU test site in 120 feet of water.

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13. ABSTRACT

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14 KEY WORDS	LINK A		LINK B		LINK C	
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