TECHNICAL REPORT NO. 71-01

STANDARD REVETMENT STRUCTURE STUDY

Final Report

By

John D. Buchanan
Munitions Branch

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August 1971

U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

This study surveys existing revetments, work being done on revetments, design of general purpose revetments, and recommends a specific revetment design.

FOREWORD

This study was undertaken to:

1. Survey Existing Designs

2. Survey Work by Other Branches of the Armed Forces

3. Survey Commercial Revetments

4. Survey and Test Materials and Designs of Possible Revetments

5. Recommend Specifications for a General Purpose Revetment

6. Recommend a Detailed Design

7. Recommend Areas for Further Study

Colonel R. N. Woods, Air Force Civil Engineering Directorate and Mr. Joseph V. Dawsey have been most helpful in keeping the writer informed of work being done in the Air Force and at the Waterways Experiment Station, Vicksburg, Mississippi.

LTC Douglas L. Haller, U. S. Army Corps of Engineers, conceived of the need for this study and is responsible for its inception and direction. In addition, he obtained much of the information on revetments in use in Vietnam.

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INTRODUCTION

Although the Army uses revetments extensively, there is not available in the supply system a material specifically designed for use as a revetment. Revetments in use generally are constructed from available materials. The most popular material is M8A1 landing mat held together by bent reinforcing rods. Corrugated steel, plywood, and sandbags are also used. The use of these materials results in the expenditure of excessive amounts of troop and equipment hours constructing the many different designs.

Many of the designs observed, especially those over 5 or 6 feet high, would fail if subjected to the earth pressure resulting when the fill material is wet earth, or clay.

The tendency of the fill material to force the revetment walls apart varies with composition (sand, earth, or clay) and especially with state (dry or wet). The following table shows the force theoretically developed (lbs. per square foot) at the base of a five foot high revetment.

Material	Normal (Part Dry)	Wet Saturated	Hydraulic Fluid
Sand	121 psf	388 psf	
Earth	280 psf	490 psf	
Clay	438 psf	596 psf	1012 psf

These figures are derived from the Rankin Formula for smooth retaining walls with unlimited width of earth acting against the wall. When using revetments, the thickness is limited, and the total force would probably be reduced by 20 to 30%, except, that in the case of some thoroughly wetted clays which tend to act as an hydraulic fluid, the pressure would remain high. The chart is most useful in showing the wide variation in earth forces between dry sand and wet clay.

For this study various revetment designs have been built and filled with sand, earth, and clay. These revetments have been thoroughly wetted down, and in addition, have been exposed to the weather at APG, Md. for the past year. From these tests a recommended revetment design has evolved.

CONCLUSIONS

As a result of the surveys conducted as part of this study and the tests conducted on various revetment designs, it is concluded that the revetment design presently used by the Air Force should be modified and adopted by the Army as a family of general purpose revetments having interchangeable components. These components can be assembled to form revetments of any height from 2 feet to 16 feet (in 1-foot increments), and any length (in 8-foot increments). This proposed design may be seen in Figures 38 and 39. Design changes made to the Air Force system can result in a revetment easy to assemble, light in weight, and nestable for shipping. (The proposed design change will eliminate hand reworking of the panels in the field.) This general purpose revetment may be used not only to protect aircraft, but other equipment, materials, barracks, and weapon installations such as artillery and mortar emplacements. It may also be combined with culvert sections to form personnel bunkers, which, when covered by sandbags, will withstand enemy mortar rounds up to 82mm. In addition to stopping fragments from shells, rockets, and bombs which explode near-by, the revetments are thick enough to be capable of defeating small arms fire, automatic weapons, and small caliber machine gun fire. The proposed revetments are self-supporting and will stand by themselves in wind, helicopter downwash, or explosive over-pressures without pilings, or base support structure. In addition, the revetments are wide enough to be easily filled by front end loaders.

COMPARISON OF EXPEDIENT AND PROPOSED KIT REVETMENTS

The concept of making revetments from materials not intended for such a use normally results in:

1. Excessive time in obtaining a list of materials.

2. Excessive time in modifying or reworking material so it can be used.

3. Very excessive time to construct or assemble expedient revetments. An example of this is found in Reference 1, where the actual assembly time, man-hours per linear foot of 5-foot high revetment, is recorded.

Assemble Kit - .076 man-hours/linear ft.
Construct from M8A1 - 1.16 man-hours/linear ft.

In this illustration the time to assemble a revetment using M8A1 matting and drilling holes and wiring these plates together and sinking pickets takes 15 times as long as fitting a kit design together.

4. Excessive cost, weight, and shipping volume. M8A1 landing mat cannot be nested and is much thicker than the proposed material. As an example: The M8A1 landing mat is .125 inches in thickness and has a 1-inch stacking dimension, compared to .049 thickness and .049-inch nesting dimension for the revetment kit. A comparison of M8A1 expedient A-shape design with no fill material, versus the proposed kit, for a UH-1 helicopter revetment, is presented.

	M8A1	Proposed Kit
Cost	$1,360 (13¢/lb.)	$580 (11¢/lb)
Weight	10,430 lbs.	5,280 lbs.
Shipping Volume	124 cu. ft.	32 cu. ft.
Assembly Time	116 man-hours	7.6 man-hours
Fill	None	$84

Whether the revetment has no fill, one foot thick fill, or four foot thick fill, the cost of the fill is insignificant in comparison to the material cost of the M8A1 landing mat, and the man-hours involved in constructing expedient designs.

While it is recognized that one foot thick revetments filled with dry sand will stop a large percentage of fragments from ordnance exploding near-by, it does not mean that wet sand, earth, or clay will be as efficient. In addition, it is felt that general purpose revetments should be capable of defeating small arms fire, automatic weapons, and small caliber machine gun fire.

During the period that work has been done on this project, two recommendations have been made from the field through ORLL's [2,3]: One, that each revetment have a prepared base consisting of a poured concrete footing; second, that each revetment have a cover which will prevent rain from entering the top of the revetment. The recommendation for concrete footings appears reasonable for all revetments over 6 feet high. It is felt, however, that a revetment up to 6 feet high may be erected on level ground, be stable, and not sink into its base. The recommendation for a cover appears reasonable as a requirement. However, in areas where water can stand on the ground, or the ground water pressure is high, the revetment fill may absorb moisture to substantial heights by capillary action. In addition, it should be understood that during the rainy season there will be a substantial increase in the moisture content of fill materials. Even in revetments with covers, water will ingress through seams and holes in the revetment material, and moisture in the air will be absorbed by the fill material. It is unrealistic to think that the fill material will be "dry" during the rainy season. However, the use of covers for the revetments should prevent excessive earth pressures due to hydraulic pressure, and will substantially reduce the tendency for the fill material to be washed out of the revetments.

SURVEY OF EXISTING DESIGNS

While there are many different expedient revetment designs, they appear to fall into four main categories:

1. M8A1 Landing Mat Revetments
2. Plywood or Coorugated Steel Revetments
3. Filled Oil Drums
4. Filled Shipping Containers

M8A1 Landing Mat Revetments:

The M8A1 matting revetments up to about 5 to 6 feet high are usually made of the mat material and bent reinforcing rods. This system is described in detail in Reference 1. Figures 1 and 2 show an M8A1 matting revetment which had been hit by a mortar round. As can be seen, the damage is not extensive.

Figure 3 shows a nine foot high revetment made of M8A1 matting and bent rods. A revetment this high is especially likely to fail because of wet earth pressure if there is no cover over the top.

Figure 4 shows a sloped wall revetment constructed of M8A1 matting, pickets, and tie wires being filled. Figure 5 shows an aerial view of M8A1 earth filled revetments.

In summary, the use of M8A1 landing mat material in revetments results in a heavy, costly, time consuming revetment which tends to fall apart during the rainy season if not properly reinforced and covered (see Reference 2).

Plywood or Corrugated Steel Revetments:

The second most popular revetment is made of plywood or corrugated steel held together by nailed or bolted 2 x 4's or 4 x 4's. Figures 6 and 7 show various stages in the construction of a four foot high earth filled revetment used to protect a barracks. Figure 8 shows this type of revetment used to protect the UH-1 helicopter.

The unsymmetric sloped wall design shown in Figures 9 and 10 show a 10 or 11-foot high revetment used to protect the CH-54 and CH-47 helicopters. Although this type of revetment has been constructed extensively in Vietnam, Reference 3 indicates that these revetments, because their offset center of gravity produces a steady turning moment, tend to lean within a relative short period of time.

The following tables show a comparison of the corrugated steel and wood revetment to the proposed kit:

Item	Corrugated Steel and Wood, 6' High	Proposed Kit
Cost (Steel)	$360 (11¢/lb)	$580 (11¢/lb)
Cost (Wood)	$276 (15¢/ft)	----
Weight	7830 lbs.	5280 lbs.
Shipping Volume	170 cu. ft.	32 cu. ft.
Assembly Time	116 man-hours	7.6 man-hours
Fill	Same	Same

A comparison of 4-foot high corrugated steel and wood revetment to the proposed kit, 4-foot high, is made below. In actual practice as the revetment gets higher the ratio of wood to steel increases.

Item	Corrugated Steel and Wood, 4' High	Proposed Kit
Cost (Steel)	$220	$386
Cost (Wood)	$140	----
Weight	4480 lbs.	3520 lbs.
Shipping Volume	93 cu. ft.	22 cu. ft.
Assembly Time	25 man-hours	5.1 man-hours
Fill	Same	Same

In summary, the corrugated steel or plywood and wood revetments are competitive with the proposed kit, in cost and weight, for the lower heights - say 4 or 5 feet and under. They become less and less competitive as the height is increased, because additional lumber must function as an open truss capable of supporting higher and higher loads. In the table shown, the assembly time is estimated and is not taken from actual work records, so this advantage of the kit has not been confirmed. The life of lumber when exposed to the weather is not considered competitive with the kit material. In addition, if there is a requirement for disassembly and re-use, then the kit would be more competitive than the corrugated steel or plywood and wood revetments.

Filled Oil Drums:

The third category of expedient revetments is sand or earth filled oil drums, which may be stacked with one row on top of two rows. These designs usually have sandbags around or on top to increase their effectiveness. When filled, these drums stop a large percentage of fragments from exploding ordnance and should be effective against small arms fire. Figure 11 shows steel drums and sandbags used to protect a barracks. Figure 12 shows steel drums and sandbags used to protect helicopters. While these units have functioned acceptably, and are of value as an expedient revetment, their limitations are height and availability of the drums. In addition, the sandbags presently in use have a short life. However, the problem of short life of the sandbags should be substantially improved as the new acrylic sandbags come into greater use.

A comparison of a UH-1 revetment made of the proposed kit to a revetment made of fifty-five gallon steel drums is shown in the following chart:

	Drum 18 Gauge	Drum 16 Gauge	Kit
Weight (ea)	50 lbs.	62 lbs.	----
Total Weight	9000 lbs.	11,120 lbs.	5280 lbs.
Volume	2160 cu. ft.	2160 cu. ft.	32 cu. ft.
Cost (steel)	$1,170	$1,440	$580

The weight of a UH-1 revetment made of steel drums is twice the weight of the kit. The volume of the steel drums is sixty-seven times larger than the volume of the kit and the cost of the steel drums is two or three times the cost of the kit. In view of the fact that steel drums can normally be re-cycled, they are not considered competitive with the kit revetment.

Filled Shipping Containers:

The fourth category of expedient designs is similar to the used oil drums in that they are used shipping containers. Figure 13 shows one style of container which has been used as a helicopter revetment. The particular design shown would be difficult to fill completely with sand or soil because of the seam along the horizontal centerline. In addition, the availability and excessive volume preclude the use of these containers except in expedient conditions.

There are undoubtedly many other revetments which have been designed and constructed, some of which have stood and some of which have failed. It is important to recognize that a standard kit will substantially reduce the man-hours involved in designing and assembling revetments from available materials not intended for use as revetments.

SURVEY OF WORK BY OTHER SERVICES

The Air Force Weapons Lab., Kirkland Air Force Base, New Mexico, has done a great deal of work in developing and testing revetments used to protect aircraft. While our literature survey did not go back beyond 1964, apparently the earliest work done by the Air Force is recorded in Reference 4 which was published in 1966.

In summary, this report compares soil, cement blocks, and filled rigid corrugated asbestos bins, sand filled fiberglass bins, and 3/8-inch thick steel pilings. The revetments were 10 to 12 feet high and of various thicknesses. The construction time varied from 1 hour per linear foot for the fiberglass bins, to 7 hours per linear foot for the soil cement blocks. The cost varied from $27.00 per linear foot for the asbestos bins, to $155.00 per linear foot for the fiberglass bins. Most of this information is now out of date. In addition to these revetments, the Air Force also tested soil filled timber bins and sandbag revetments. These tests are discussed in detail in Reference 5.

Apparently, most of these designs were considered inadequate, either because of labor and cost, or because of inability to defeat small arms fire.

This work by the Air Force did result in the development of a light gauge, square corrugated, sheet steel revetment, which appears to be the most competitive design existing.

These revetments, originally produced by Republic Steel, are 12 feet high by 5 feet 3 inches wide, or 16 feet high by 6 feet 11 inches wide. They are presently being manufactured by The Marwais Steel Co., San Francisco, Calif. In discussions with Air Force personnel it appears that these revetments are always filled with sand, but usually have the lower two feet filled with gravel to prevent the capillary lifting of water up into the revetment fill.

While Air Force personnel have talked about wetting down the fill with a hose, it is doubtful that the revetments are capable of withstanding the earth loads resulting when the fill material is thoroughly wet. The use of a cover to protect the fill would tend to prevent the build-up of hydraulic pressure inside the revetments. Under such circumstances they should be able to fulfill their function with a low probability of failure due to excessive moisture.

In addition to the work on revetments, a great deal of work has been done on various soils characteristics, such as resistance to fragment penetration, and shock wave transmission and attenuation, by many different research organizations. Most of this work has been done for the Air Force Weapons Lab., and for or by the Waterways Experiment Station. Also, some work has been done by US Naval Civil Engineering Laboratory, Port Hueneme, Calif.

A bibliography of the reports of the above work was prepared by Defense Documentation Center for this study, but is not included as a reference since it is not directly applicable.

The US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss. has done extensive work on revetments. Most of the work has been to protect helicopters from ordnance fragments, with revetments made from materials available in the field. Reference 6 considers a number of designs which use expedient materials such as M8A1 matting, and 12-inch by 12-inch timber posts, for revetments up to 11 feet high. Because the revetments are only one foot thick, it is necessary to sink pilings every 6 feet or so. In general, the comments on expedient materials revetments previously made in this report apply to these designs. The work done by Waterways Experiment Station, reported in Reference 7, is used as a basis for information presented in the survey of useable commercial revetments, and for some of the information presented in the Survey of Existing Designs. An effort has been made to use information of this type in the study rather than to duplicate it.

There appears to be no work being done by any of the services on a general purpose revetment kit, except that the Air Force has a kit design which it uses for self standing revetments 12 feet and 16 feet high. While these kits meet the Air Force requirements, they are too high and too thick for most Army applications. Most revetments around barracks are about 4 feet high. Around the UH-1 helicopters they are 5 feet 6 inches high nominally, but may be 6 or 7 feet high if fill is put inside the revetment where the helicopter sits. The Army also has some 9 foot and 11 foot revetments which are used around the CH-54 and CH-47 helicopters.

An Air Force type revetment system, 3 1/2 feet wide x 4 to 8 feet high, would be self-standing and would meet a large percentage of the Army revetment requirements. For higher units the base width would need to be increased to retain the self-standing feature of the basic design. For revetments 8 feet to 12 feet high, a base width of 5 feet 3 inches would meet both Air Force and Army requirements; and revetments 13 to 16 feet high by 6 feet 11 inches wide would also meet both Air Force and Army requirements. Revetments over 6 feet high would require a prepared concrete base.

SURVEY OF COMMERCIAL REVETMENTS

A survey of a number of commercial revetments, including erection, filling, and disassembly, was made by the Waterways Experiment Station and is reported in Reference 1. Similar work was conducted by the Air Force and reported in Reference 4. In general, this work indicated that commercial kit designs were cheaper, weighed less, and could be more quickly erected than expedient revetment designs. However, in a number of cases, the commercial material deformed or buckled to some extent.

Various manufacturers, e.g. Kaiser Steel, ARMCO Steel, and Republic Steel, have brochures on revetment systems, and appear to be capable of delivering a commercial system on short notice. Kaiser Steel and ARMCO have modified their designs somewhat to reduce cost and improve the durability. The Kaiser Steel system (see Figure 14) has been purchased and erected in Vietnam by the Army. It has survived the Vietnam weather for several years.

In summary, the commercial revetments are very competitive with the proposed kit design. However, the use of a corrugated steel makes the proposed kit much stronger, more rigid, and much more flexible in height variation. The kit - by alternating 2-foot high and 3-foot high panels - can produce revetments of any height in one-foot increments. The commercial designs are either 5, 10, or 15 feet high. In addition, the proposed kit can withstand wet clay up to 6-foot heights. The commercial revetments tend to deform or buckle when the sand fill is wet; if filled with wet clay they would fall apart.

SURVEY OF MATERIALS AND DESIGNS

A variety of materials and designs were considered.

Materials:

The materials considered included plastics, reinforced plastics, plywood, masonite and similar materials, wax impregnated corrugated fiberboard, and aluminum and steel sheet formed into various types of corrugations. Of these materials, only the impregnated fiberboard, exterior plywood, and corrugated metal were competitive in cost.

The wax impregnated fiberboard did not make acceptable revetments, Figures 15 through 18. Boxes which were not stacked lasted for over six months when exposed to the weather at APG, Maryland. This is considered an impractically short life. The revetments made of wax impregnated panels (Figure 19) lasted only six weeks. They failed because the sand used to fill the revetment became wet and stayed wet, since the wax retained the rainwater. This weakened the panels and they broke out near ground level (see Figure 20). The wax impregnated corrugated fiberboard material has strength enough to be filled to height of 2-1/2 to 3 feet. It does not have sufficient wet strength to be filled higher and does not last long enough to be a practical material at this time. Should a waterproof paper material be developed with a waterproof glue, the use of this material might become economically practical for lower height revetments.

The plywood material (see Figures 21 through 24) is quite competitive in cost and has a good life span. However, plywood revetments higher than 4 or 5 feet require a substantial structural system for withstanding the earth loads generated. For these reasons plywood is not recommended.

A number of different designs were made using corrugated aluminum material. These are shown in Figures 25 through 29. While this material withstood the earth pressure of wet clay, and appeared to be impervious to the weather at APG, the aluminum itself was too soft to withstand the impacts when filled with loads of earth and clay by a front end loader. (See Figures 30 and 31). Aluminum is therefore impractical unless the panel thickness is increased to such an extent that the cost would become prohibitive. The revetment material tested was .050 thick aluminum, and it appeared that .090 thick aluminum would have been required. For these reasons aluminum is not recommended.

The steel paneling worked well (see Figures 32 through 35). It is the strongest and cheapest material which meets the tests of actual useage, and is recommended as the material for the standard revetment design.

Design:

Three design approaches for revetment which could be rapidly assembled were considered. These included: (1) folded boxes (see Figures 15 through 18), (2) panels with interlocking edge runners which slide together (see Figures 21 through 29), and (3) panels with locking rods (see Figures 32 through 37). The folding boxes of impregnated fiberboard were not strong enough to be stacked. If folded boxes were made of steel, the cross members would have doubled the amount of steel. For these reasons the folded box design was discarded.

The panels with metal edges which slide inside each other were stapled to plywood and riveted to corrugated aluminum. These units were very quickly assembled, and withstood the pressures of wet sand, earth, and clay. However, the impact of loads of earth and clay deformed the paneling, and twisted or broke apart some of the corners (see Figures 30 & 31).

In addition, the use of formed parts, stapled or riveted to the end of each panel, resulted in a complex assembly of parts which was not competitive with the roll-formed panels which used the locking-rod approach.

The locking rods used in the steel revetments (Figures 32 through 35) require only punched holes in the panels. These panels are punched and then roll-formed when manufactured. This means there are no secondary operations such as stapling, riveting, or welding of parts together. For these reasons the punched-hole, locking-rod, fastening system is least costly. It is also the strongest and most effective of the various designs investigated.

The cover design for the revetments is shown in Figures 38 and 39. The detail drawings are Figures 40 through 46. The overlapped corrugated plates are lightweight, strong, nestable, and are held in place by a stamped sheet metal key which locks the tops to the revetment side panels. This key can be seen in Figure 38.

RECOMMENDED MILITARY CHARACTERISTICS FOR A GENERAL PURPOSE REVETMENT

The following are the recommended Military Characteristics for the General Purpose Revetment:

1. Offer maximum protection against fragments from exploding ordnance.

2. Be capable of defeating small arms fire and automatic weapons fire.

3. Be strong enough to resist wind pressures from helicopter downwash, and winds to 110 mph.

4. Be capable of being erected in height multiples of 1 foot, from 2 feet high to 16 feet high.

5. Be lightweight and simple enough to be constructed by self-help or unskilled indigenous labor.

6. Be versatile in erection configuration and easily disassembled for relocation.

7. Be lightweight and compact so as to impose a minimum logistic burden.

8. Require no bolts, screws, or complex fasteners for assembly.

9. Include a cover to shed rain.

10. Revetments over 6 feet high must have a prepared concrete base and special "end of wall" panels.

11. Have a minimum construction cost - less than $10 per linear foot, 6 feet high.

RECOMMENDED DESIGN

The recommended assembly and detail parts drawings are shown in Appendix A. The estimated cost is $5 per linear foot, 5 feet high. This design will require some slight modification of the rolled locations on the parts presently being made for the Air Force. It should be pointed out that these parts can be punched and roll-formed (no brake operations) in one continuous operation and with no secondary operations and with no additional parts required to be welded, riveted, or fastened to the panels. For this reason the price per pound when purchased in quantity should be less than the price per pound of the M8A1 matting, which requires a number of secondary operations and to which small parts must be welded and assembled after brake-forming.

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5. Protective Revetments by D. D. Piepenburg, The Military Engineer, May-June 1968.

6. Technical Report N-69-8, Waterways Experiment Station, Vicksburg, Miss.

7. Status Report for Army Aircraft Protective Shelters Program, Draft Report August 1969, Waterways Experiment Station, Vicksburg, Miss.

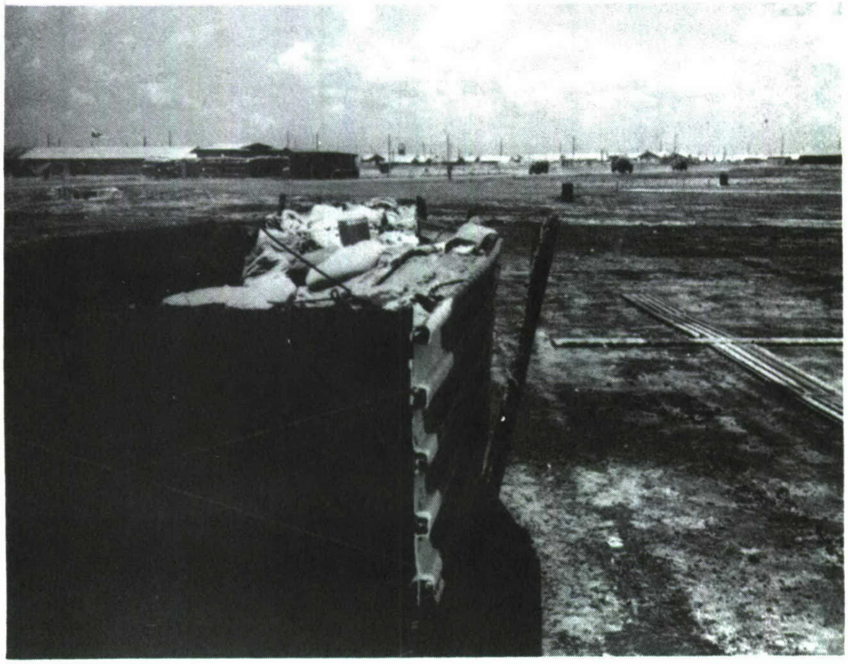


FIGURE NO. 1: M8A1 Revetment Hit by Mortar Round

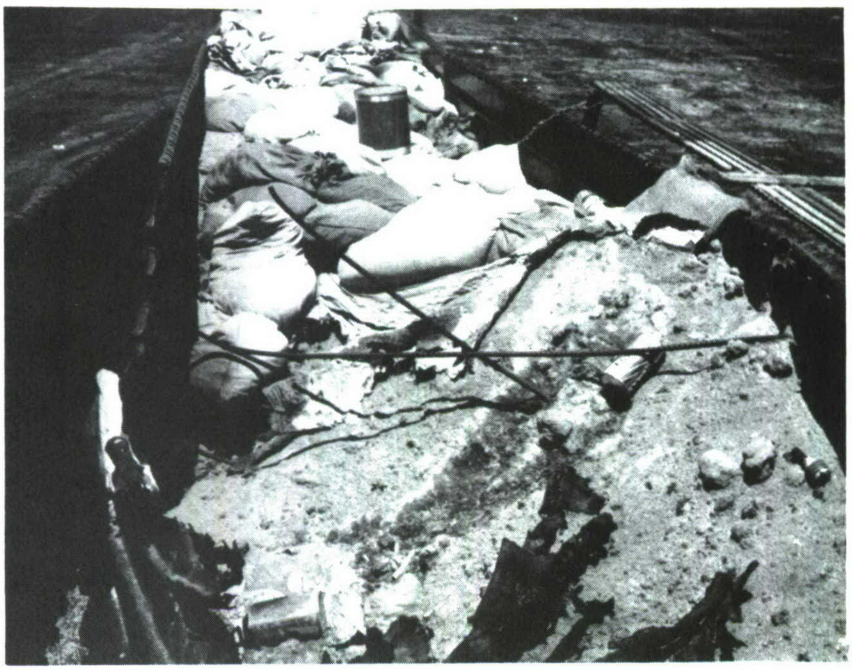


FIGURE NO. 2: Top View of Revetment Hit by Mortar Round

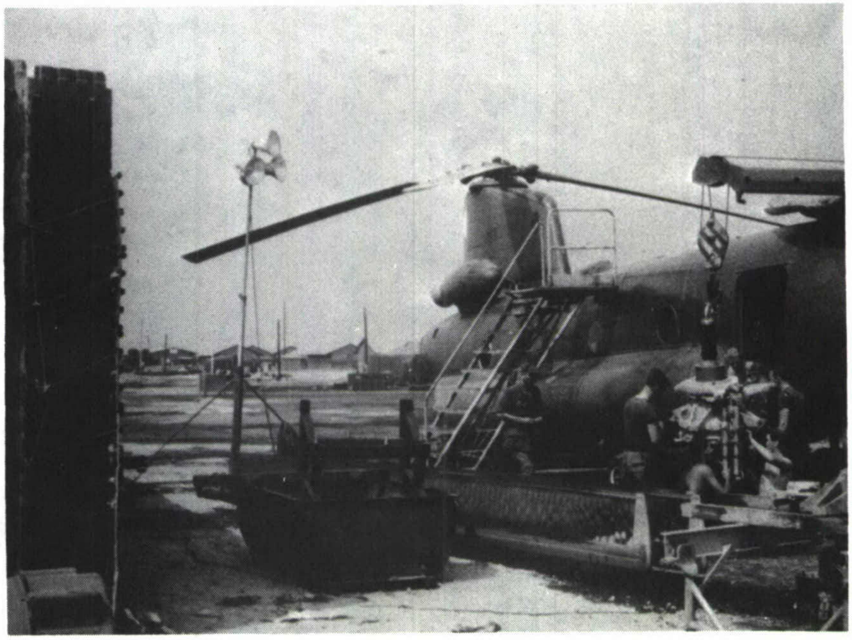


FIGURE NO. 3: Nine-Foot High Revetment Made from M8A1 Mat

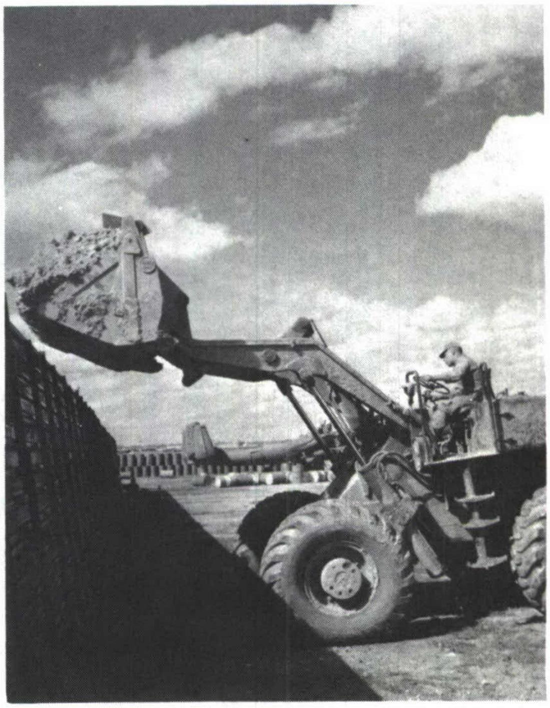


FIGURE NO. 4: Filling M8A1 Revetment Using Front End Loader

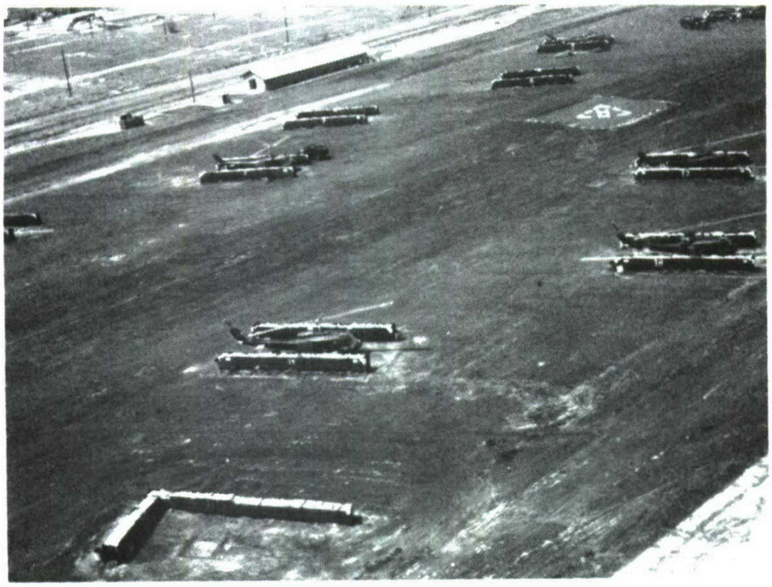


FIGURE NO. 5: Aerial View of M8A1 Landing Mat Revetments

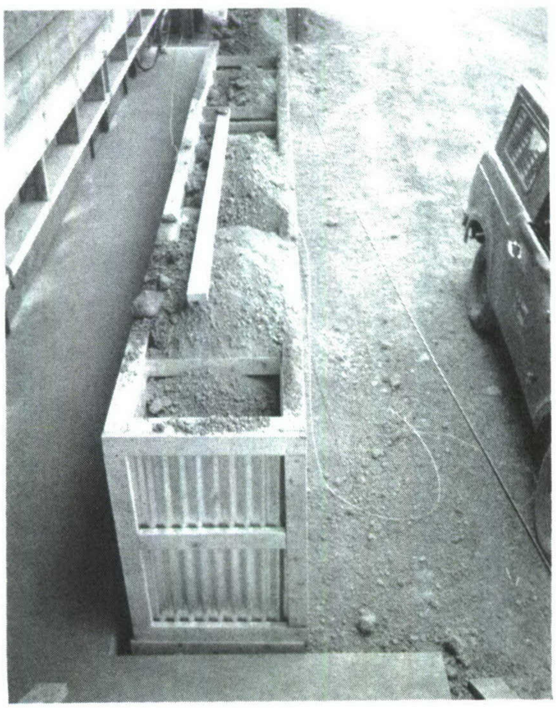


FIGURE NO. 6: Corrugated Steel and Wood Revetment Being Filled

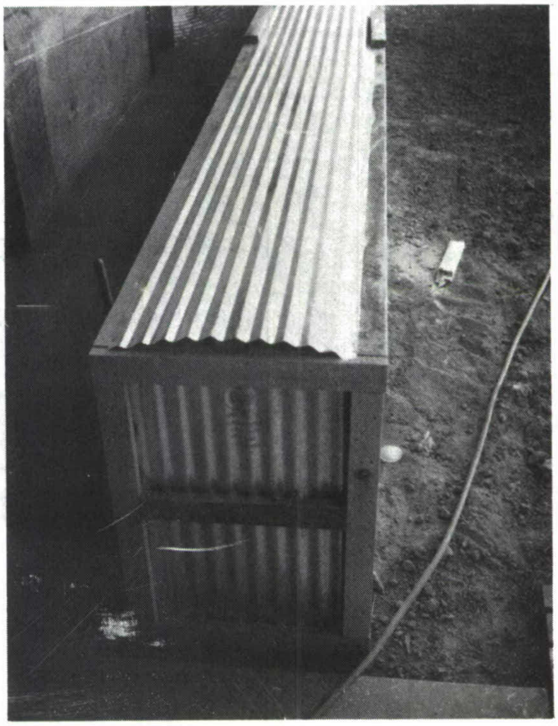


FIGURE NO. 7: Top View Corrugated Steel and Wood Revetment

FIGURE NO. 8: Corrugated Steel and Wood Revetment for Helicopter Protection

FIGURE NO. 9: Sloped Wall Corrugated Steel and Wood Revetments

FIGURE NO. 10: Three Quarters View of Sloped Wall Revetment

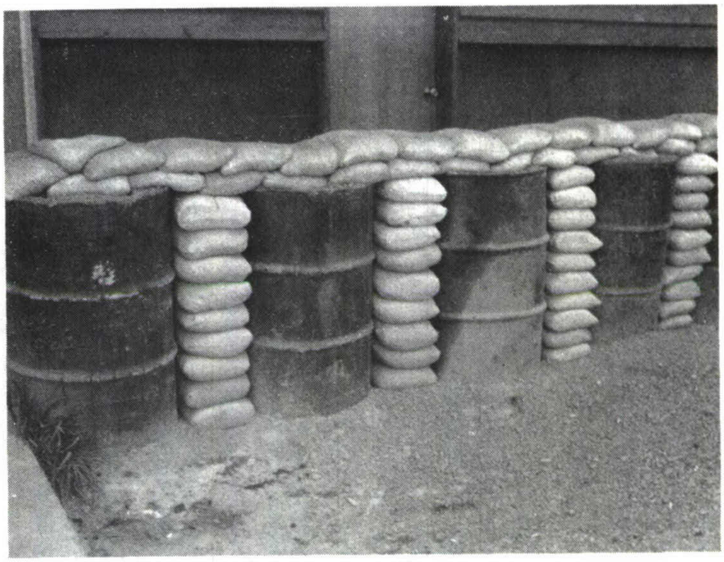


FIGURE NO. 11: Filled Steel Drum Revetment, Side View

FIGURE NO. 12: Filled Steel Drums Used to Protect UH-1 Helicopters

FIGURE NO. 13: Close-Up View of Shipping Container Used as Revetment

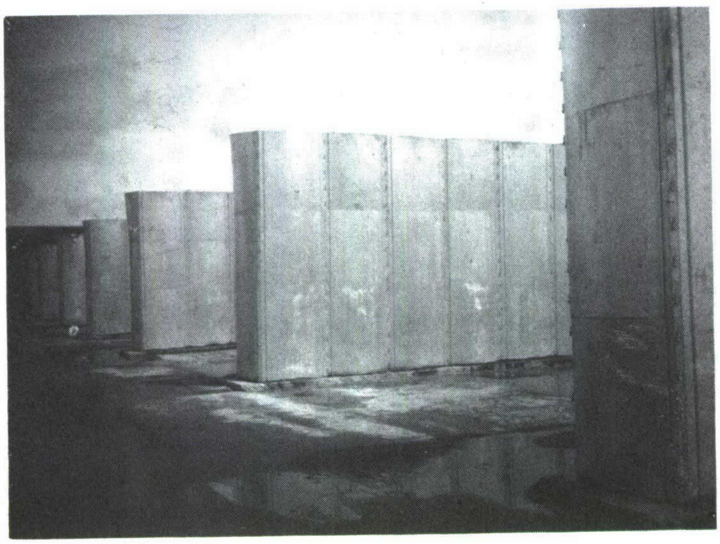


FIGURE NO. 14: Kaiser Steel Revetment Erected at Dong Tam

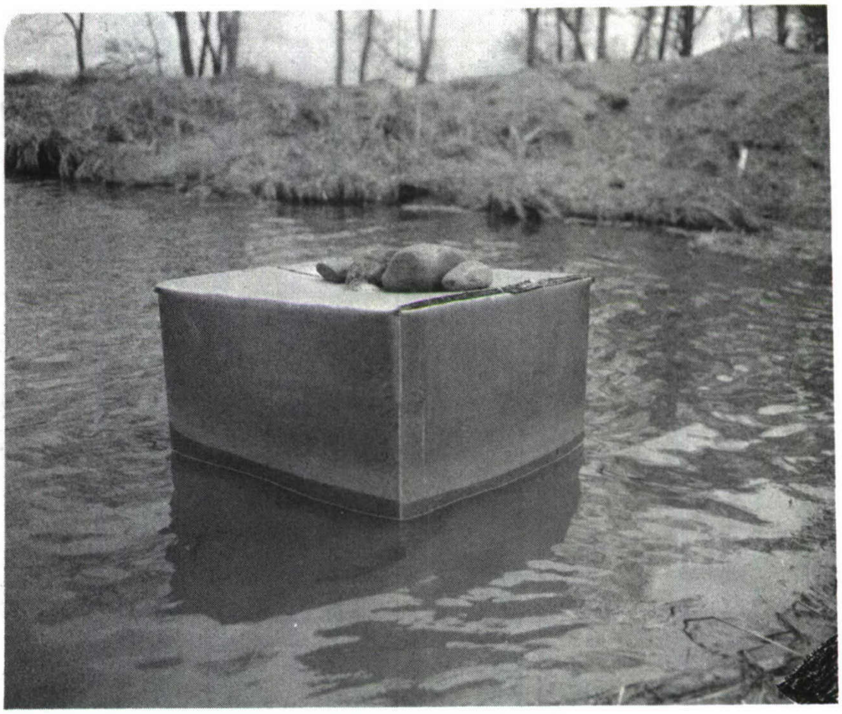


FIGURE NO. 15: Fiberboard Box in Tidal Area

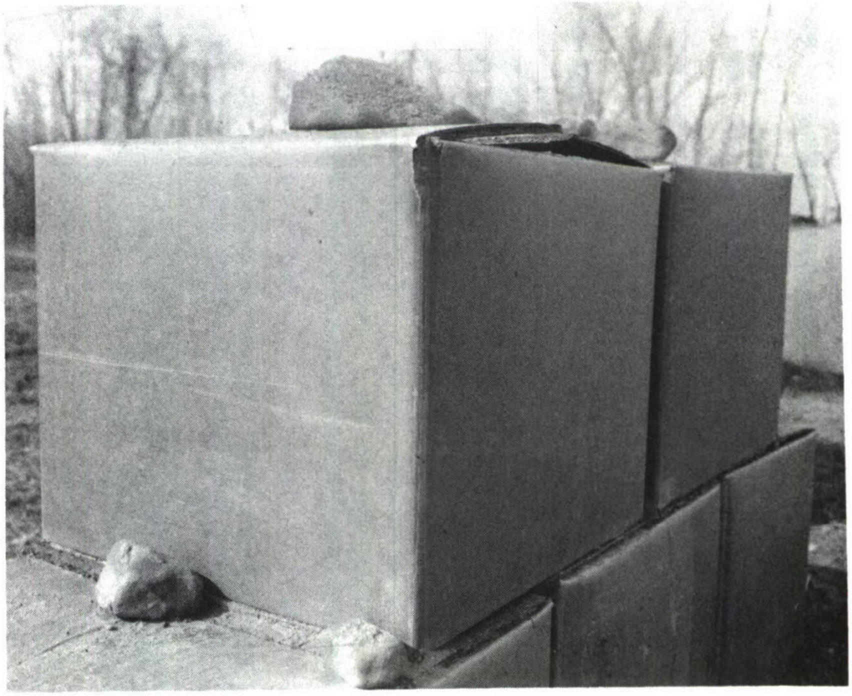


FIGURE NO. 16: Stacked Fiberboard Boxes

FIGURE NO. 17: Unstacked Open Boxes Lasted Longest

FIGURE NO. 18: Deteriorated Boxes, Six Months Exposure

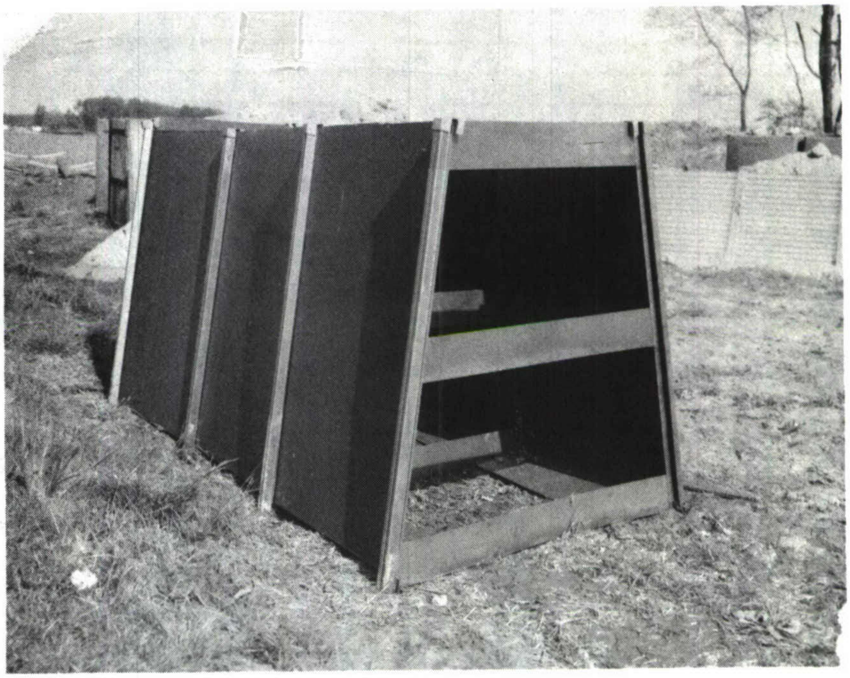


FIGURE NO. 19: Wax Impregnated Fiberboard Panels

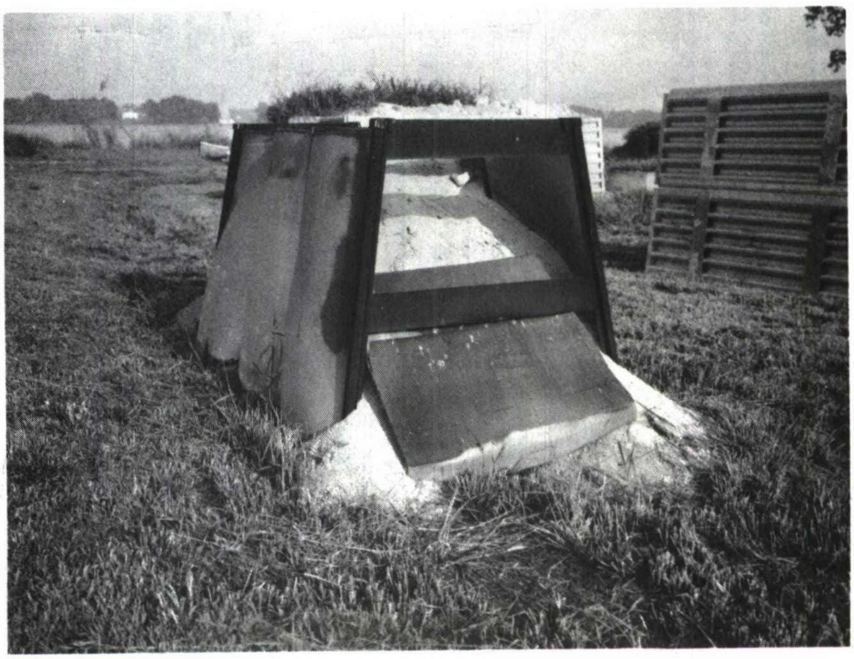


FIGURE NO. 20: Effects of Water on Fiberboard Panels

FIGURE NO. 21: Plywood Revetment When Filled

FIGURE NO. 22: Slanted Wall Plywood Revetment After Exposure to Weather for One Year.

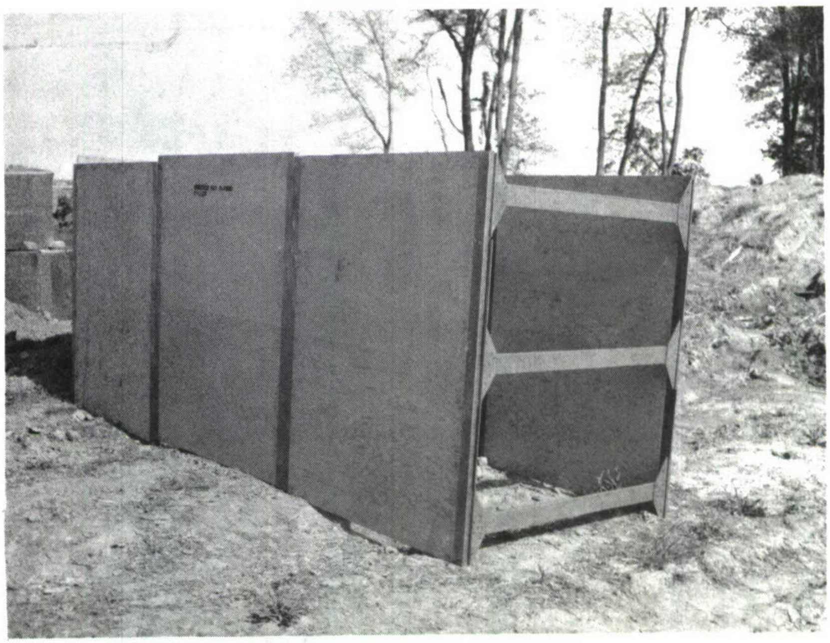


FIGURE NO. 23: Straight Side Plywood Revetment

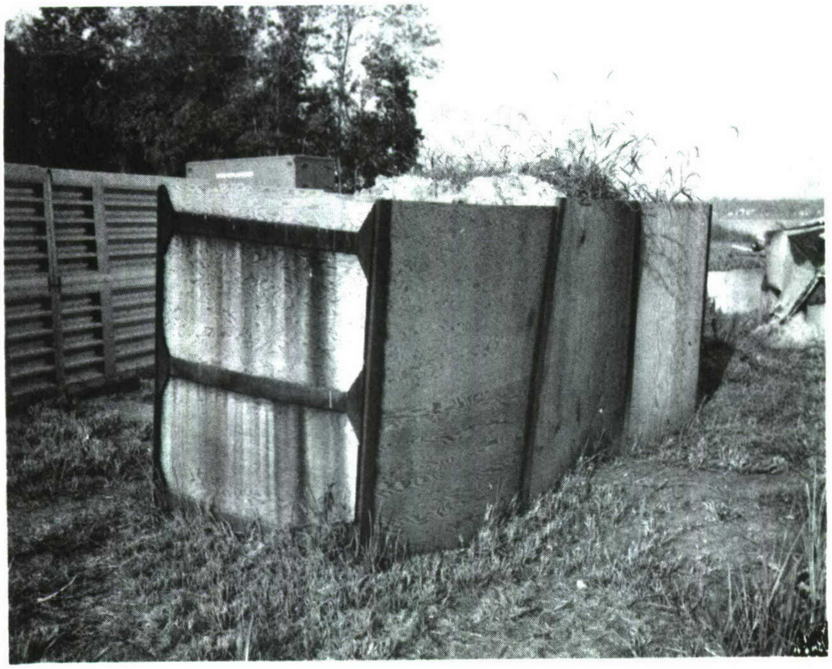


FIGURE NO. 24: Straight Side Plywood Revetment After Exposure to Weather for One Year.

FIGURE NO. 25: Assembly of Tilted Wall Aluminum Revetment

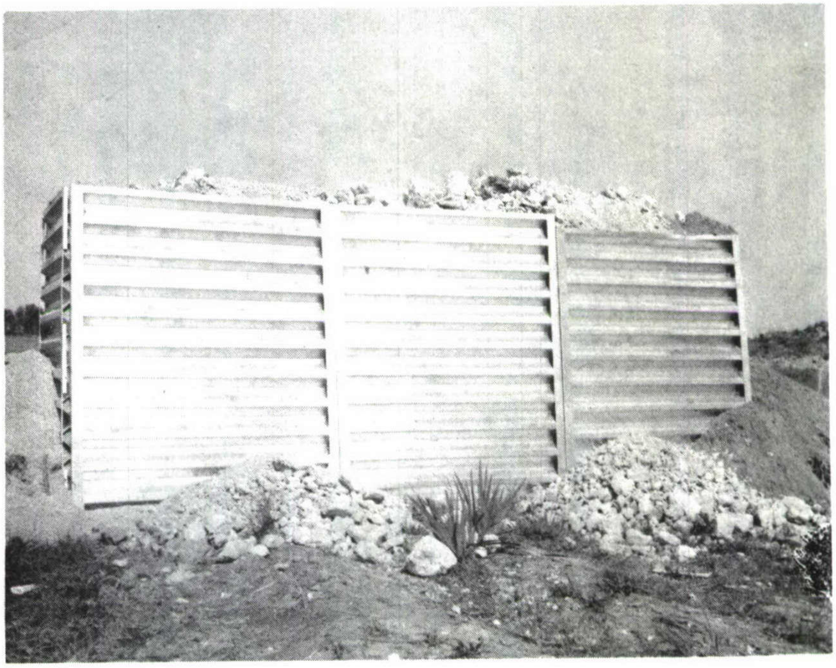


FIGURE NO. 26: Aluminum Revetment Filled with Sand, Clay, and Earth

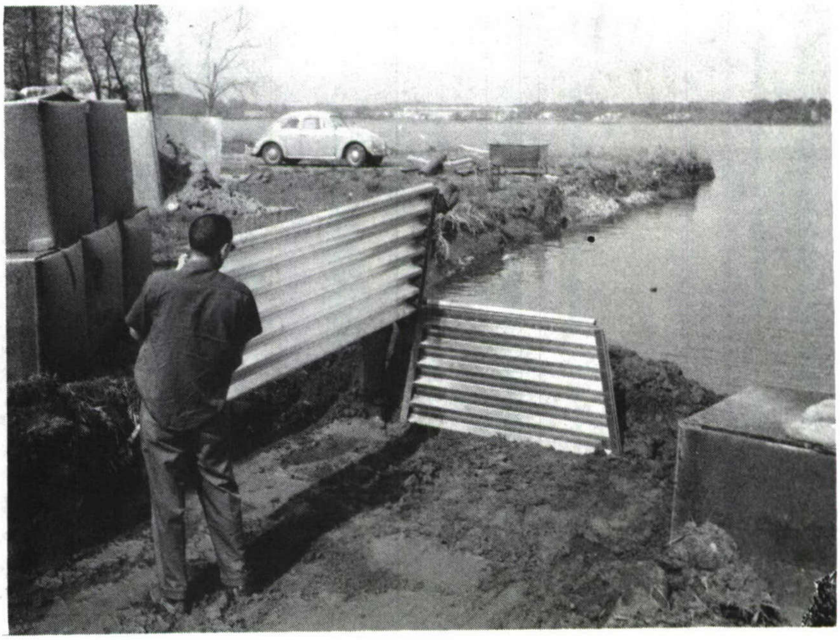


FIGURE NO. 27: Assembly of Aluminum Revetment

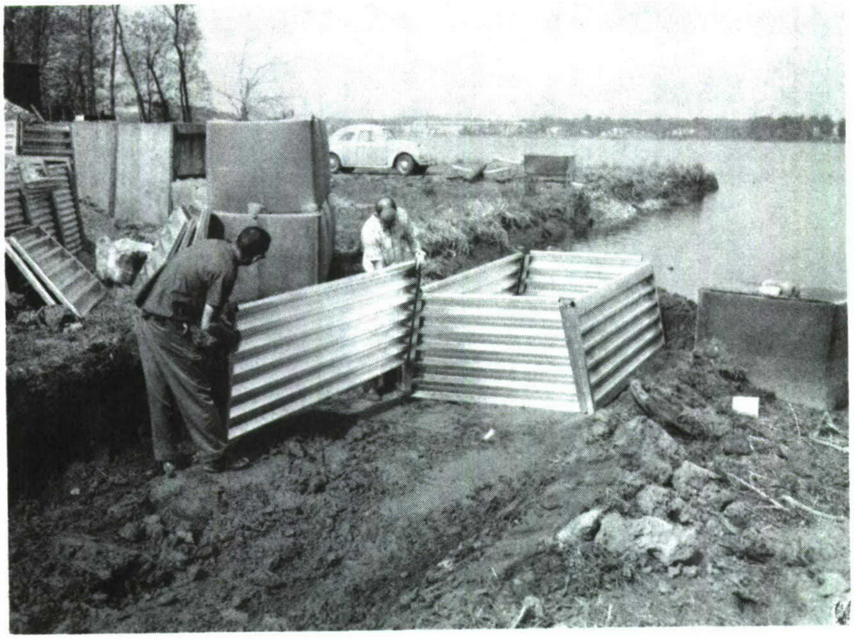


FIGURE NO. 28: Sliding Wall Panel in Place

FIGURE NO. 29: Installing Upper Cross Panel and Wall

FIGURE NO. 30: Effect of Earth Impacting Opposite Wall

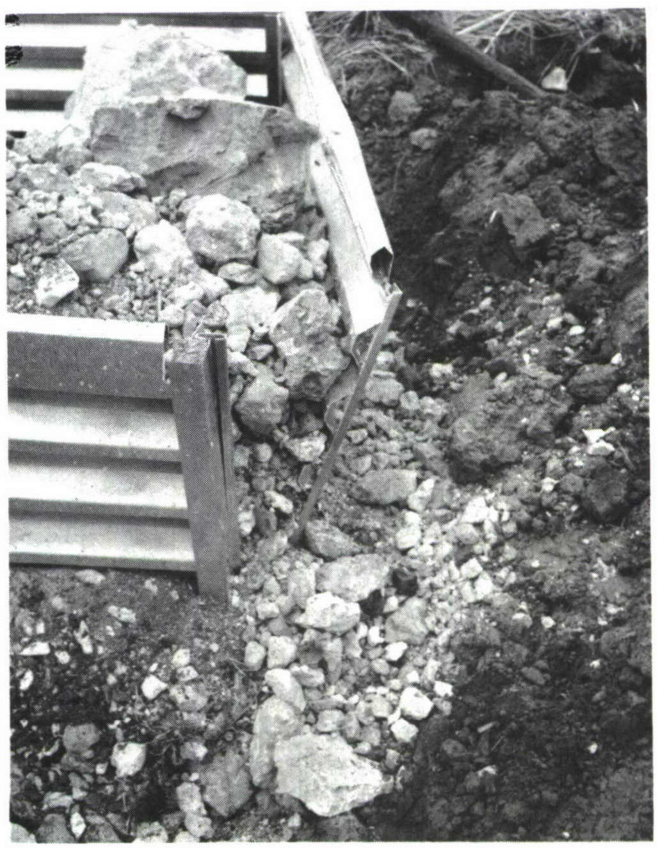


FIGURE NO. 31: Effect of Large Clay Block Hitting Wall

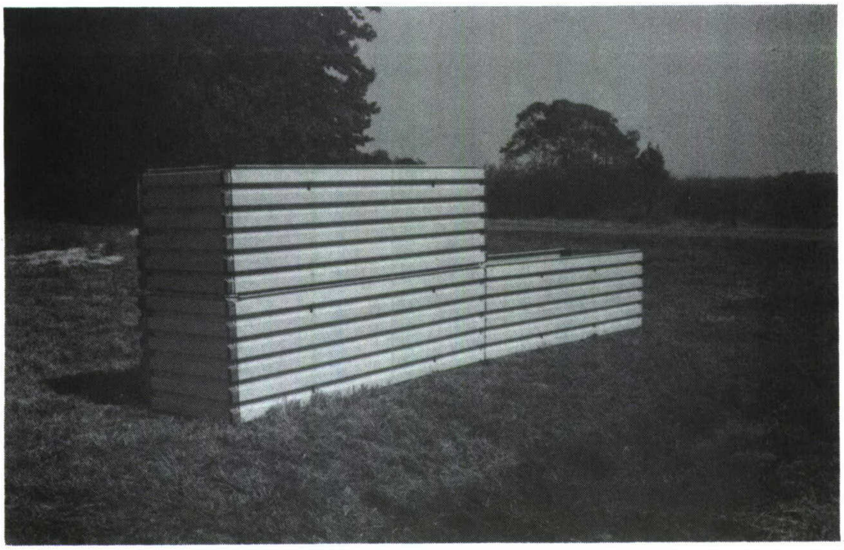


FIGURE NO. 32: Corrugated Sheet Steel Revetment

FIGURE NO. 33: Cross Bars in Steel Revetment

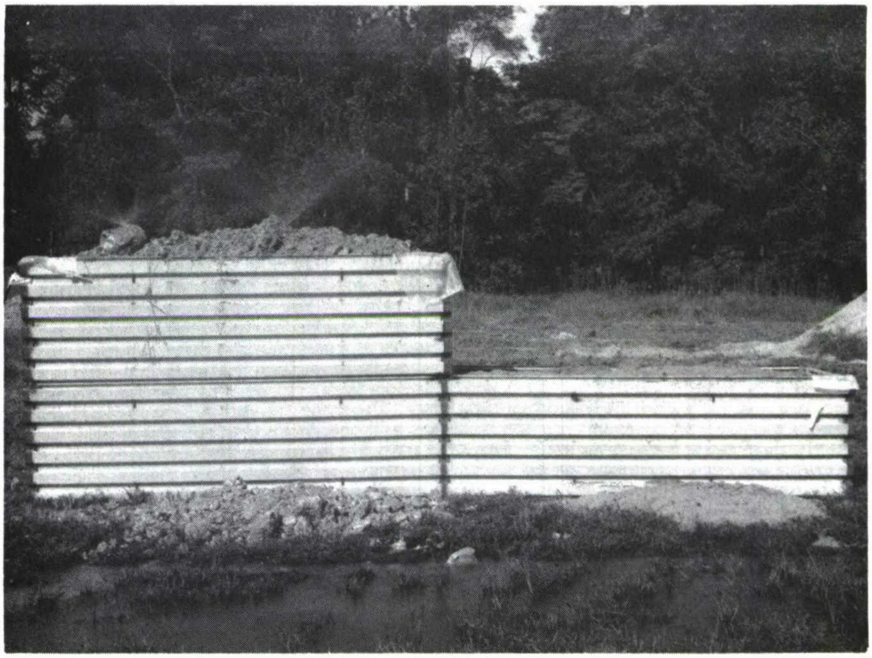


FIGURE NO. 34: Fill in Revetment Being Wet Down

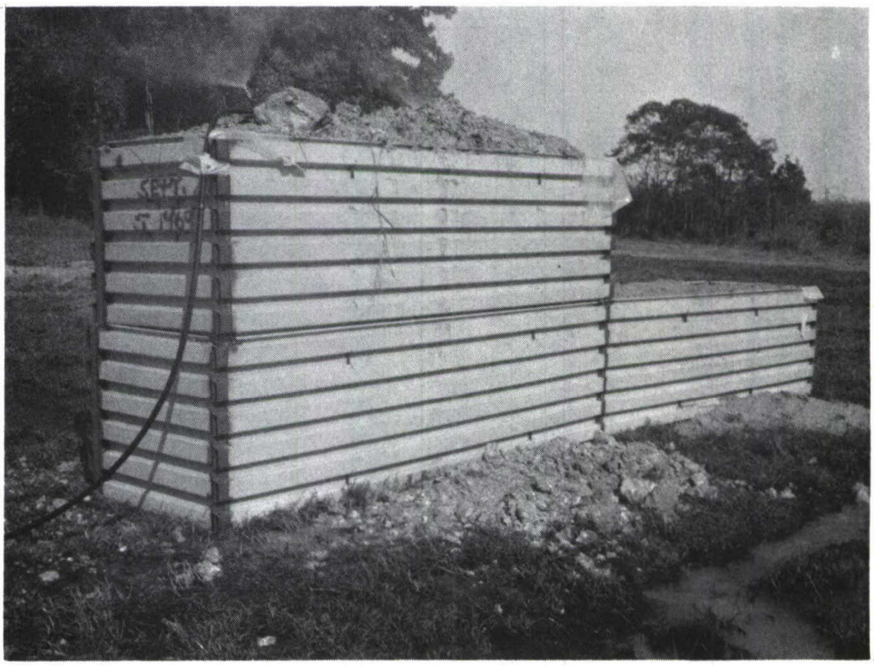


FIGURE NO. 35: Side View of Revetment

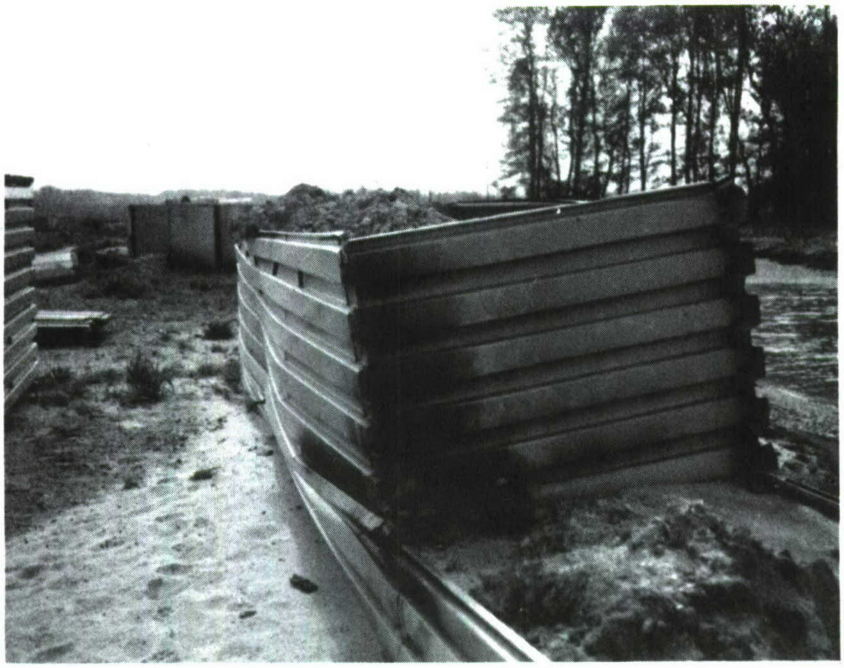


FIGURE NO. 36: Effect of Wet Clay on Thin Corrugated Steel Revetment

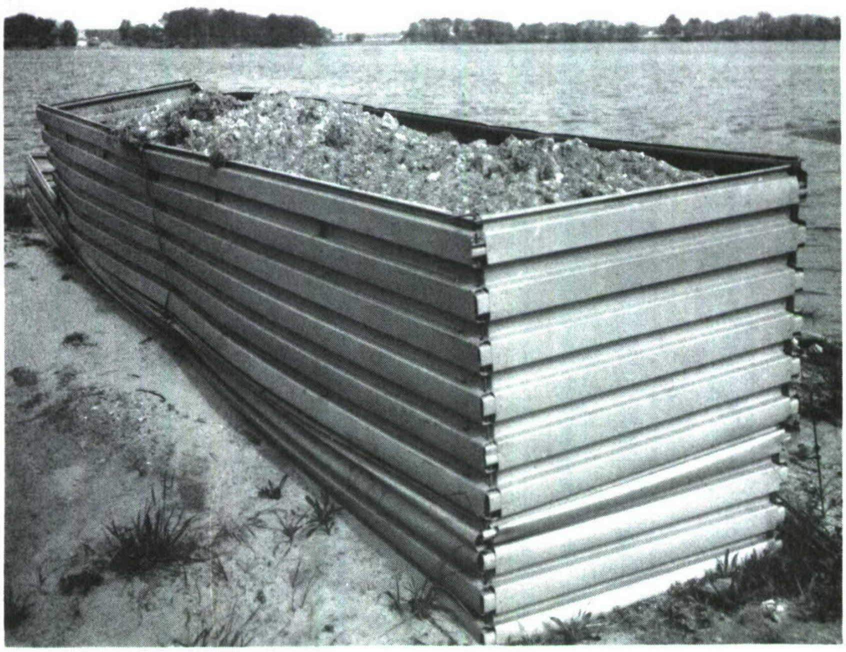


FIGURE NO. 37: Thin Steel Revetment Deformed by Pressure of Wet Clay

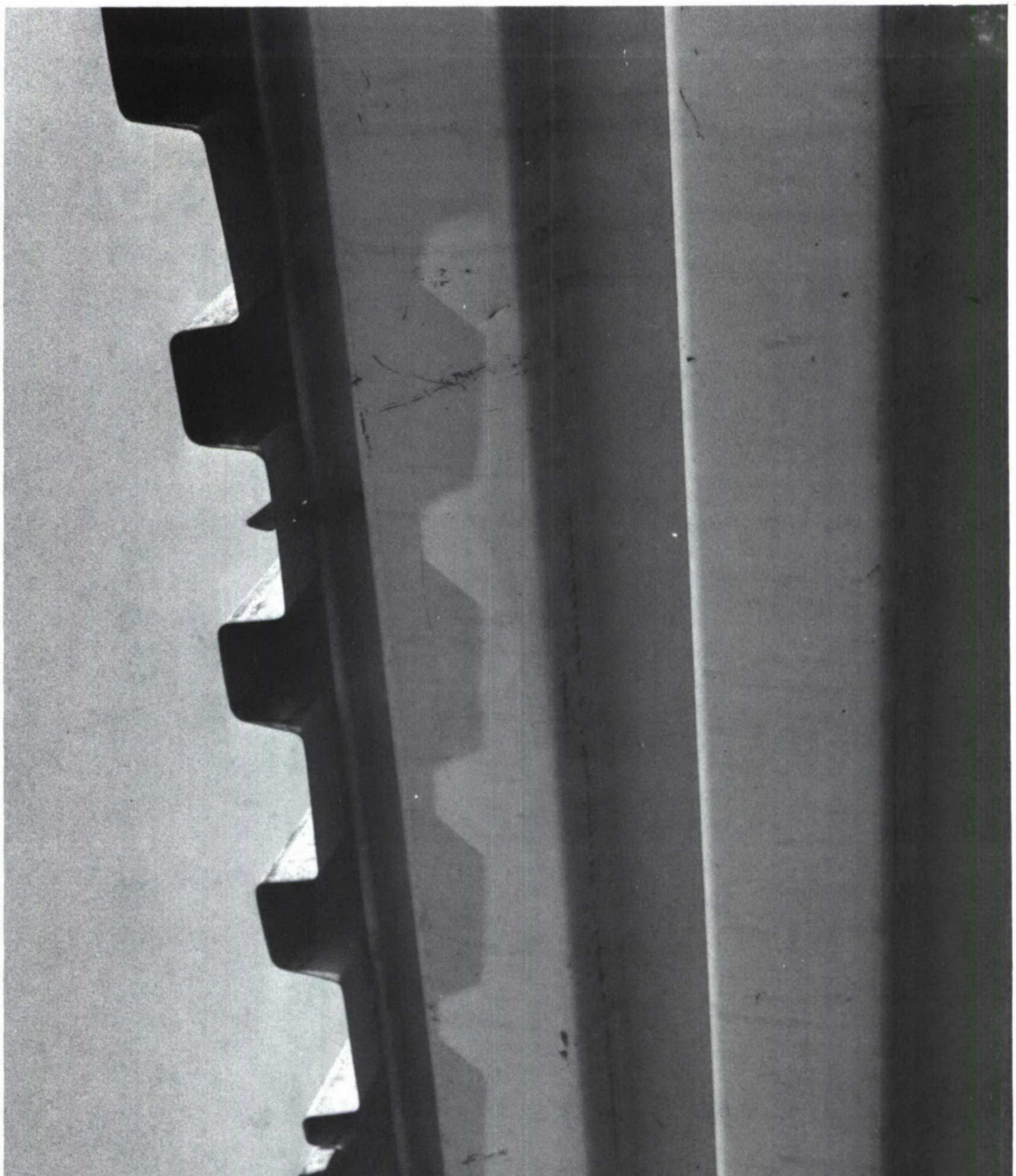


FIGURE NO. 38: Installation of Revetment Cover

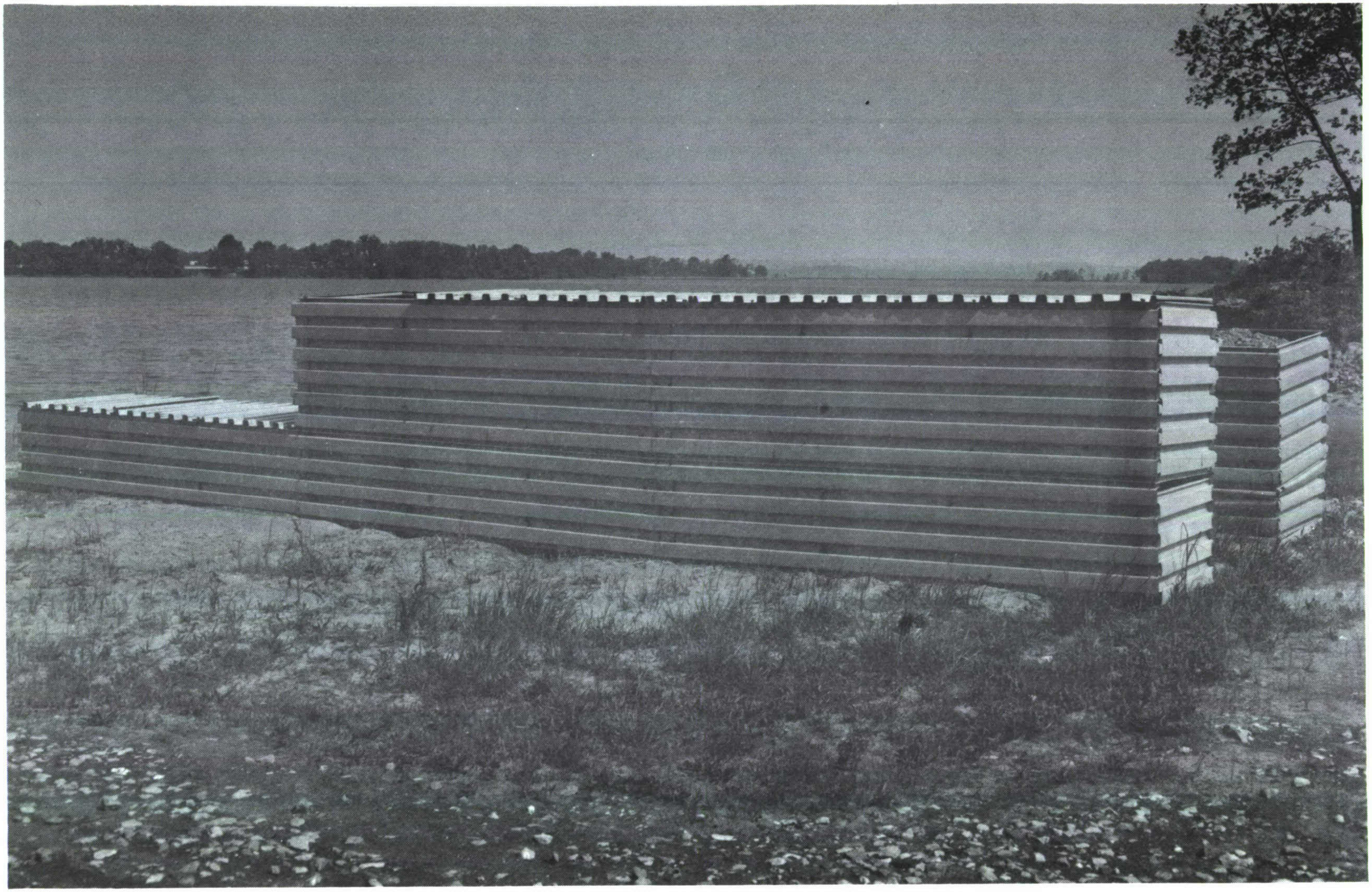
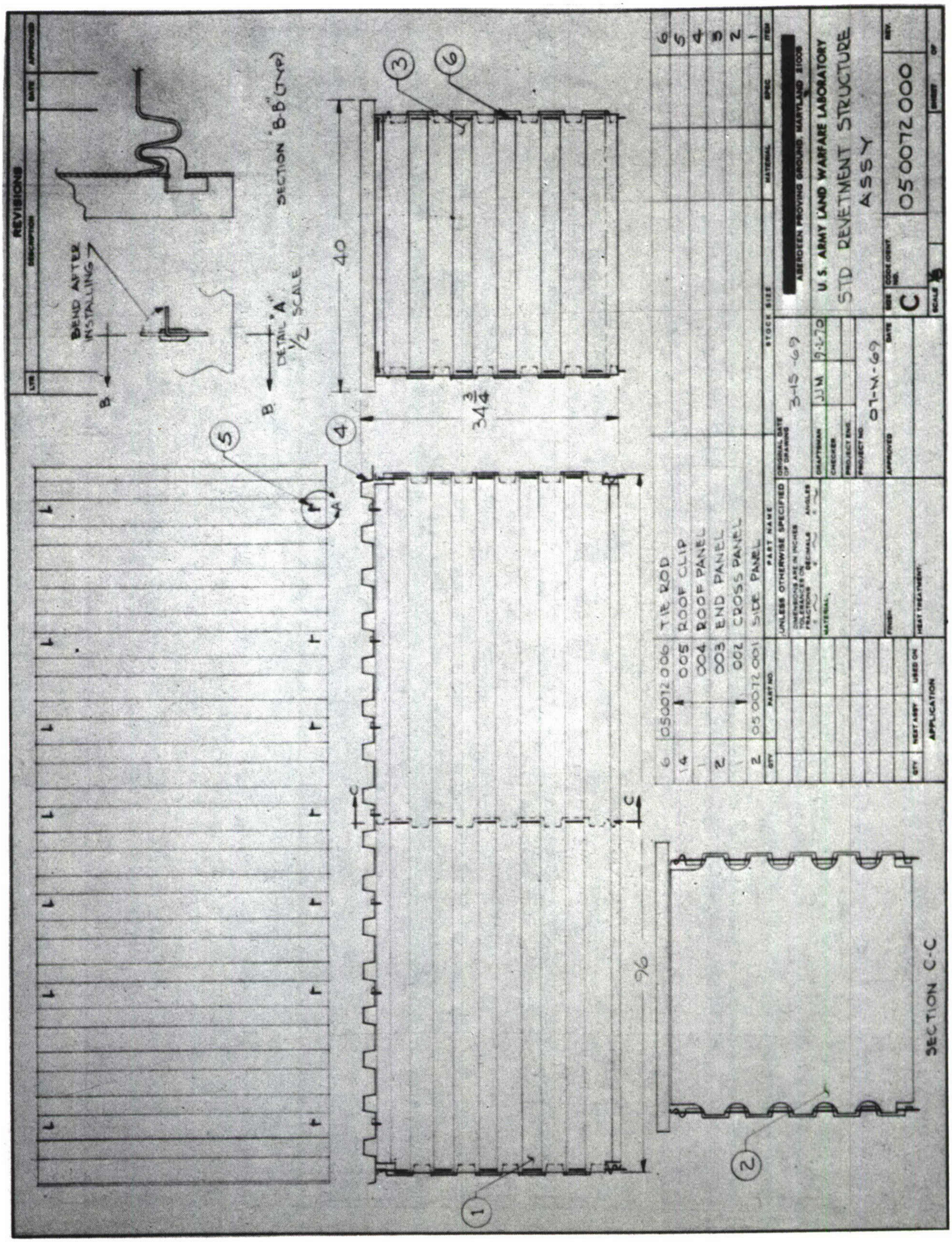


FIGURE NO. 39: Steel Revetment with Partial Cover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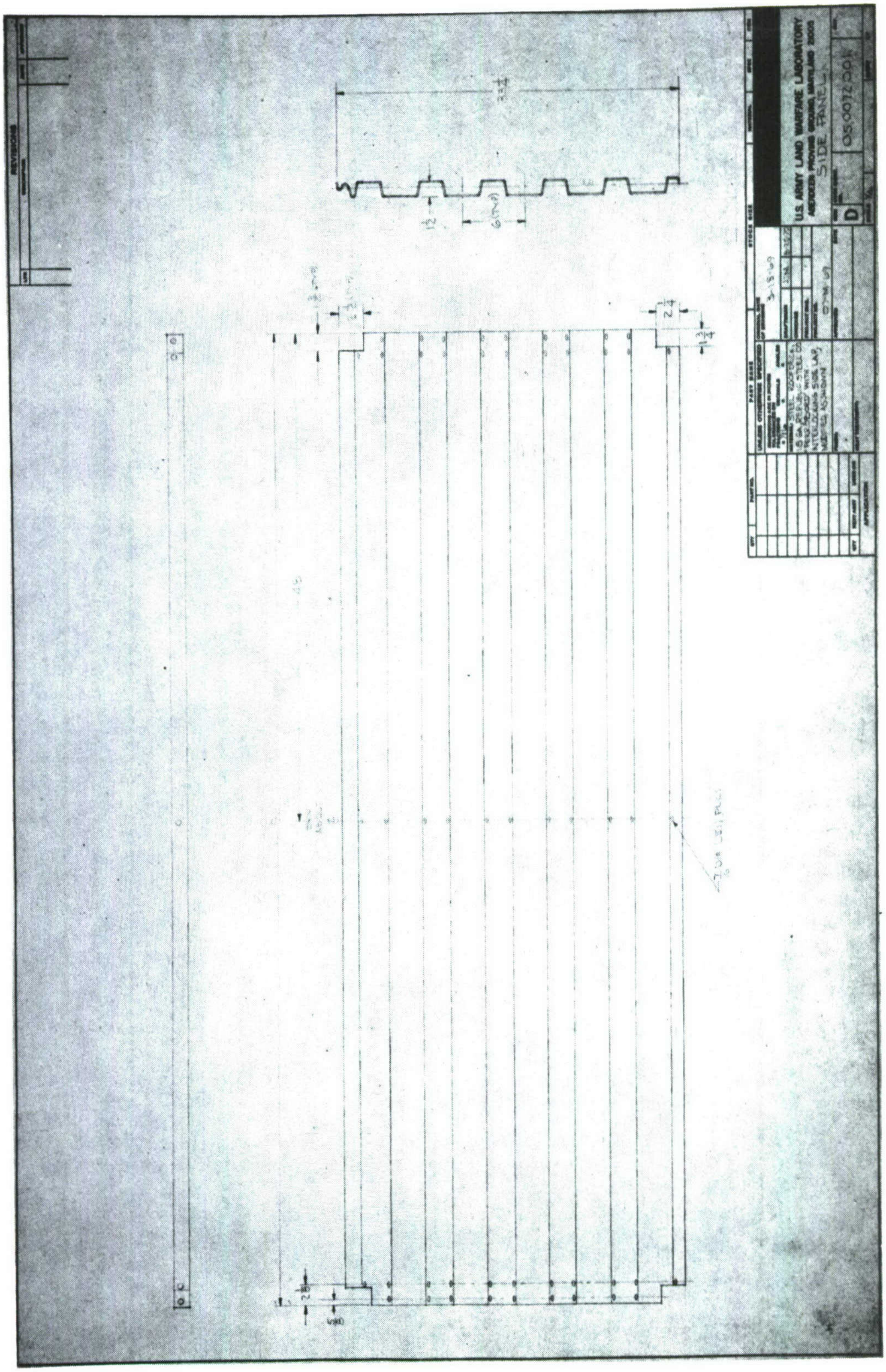
BEND AFTER INSTALLING
B
B
DETAIL "A" 1/2 SCALE
SECTION "B-B" (TYP)
5
4
3
6
1
2
40
34 3/4
96
C
C
SECTION C-C
6 | 050072 006 | TIE ROD | 6
14 | 005 | ROOF CLIP | 5
1 | 004 | ROOF PANEL | 4
2 | 003 | END PANEL | 3
1 | 002 | CROSS PANEL | 2
2 | 05 0072 001 | SIDE PANEL | 1
QTY | PART NO. | PART NAME | STOCK SIZE | MATERIAL | SPEC | ITEM
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATERIAL
FINISH
HEAT TREATMENT
ORIGINAL DATE OF DRAWING 3-15-69
DRAFTSMAN JJM 9-2-70
CHECKER
PROJECT ENG.
PROJECT NO. 07-M-69
APPROVED
DATE
[redacted]
ABERDEEN PROVING GROUND, MARYLAND 21005
U. S. ARMY LAND WARFARE LABORATORY
STD REVETMENT STRUCTURE ASSY
SIZE C
CODE IDENT. NO.
050072000
REV.
SCALE
SHEET OF
QTY | NEXT ASSY | USED ON
APPLICATION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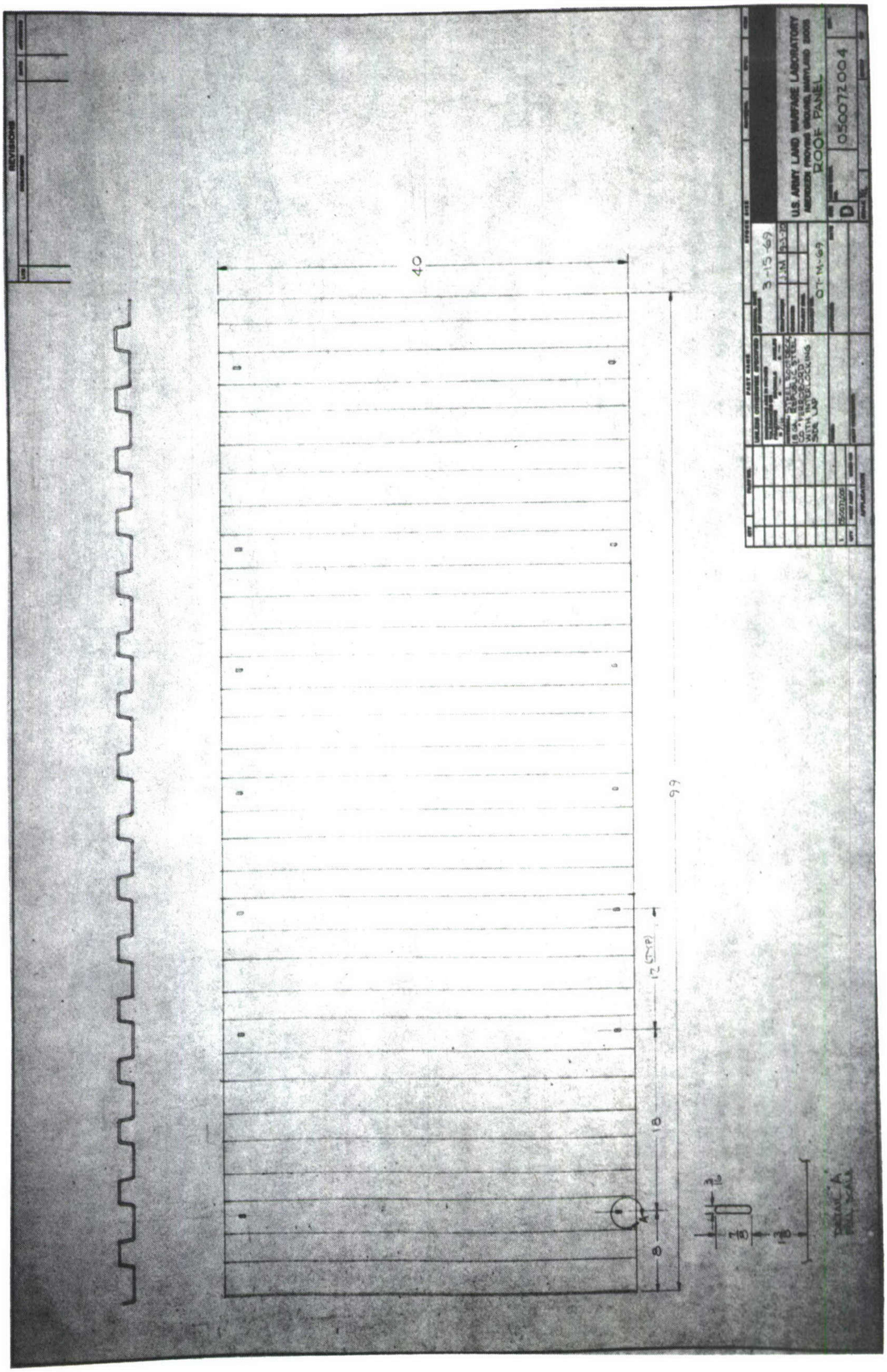
SIDE PANEL


REVISIONS
40
99
18
8
12 (TYP)
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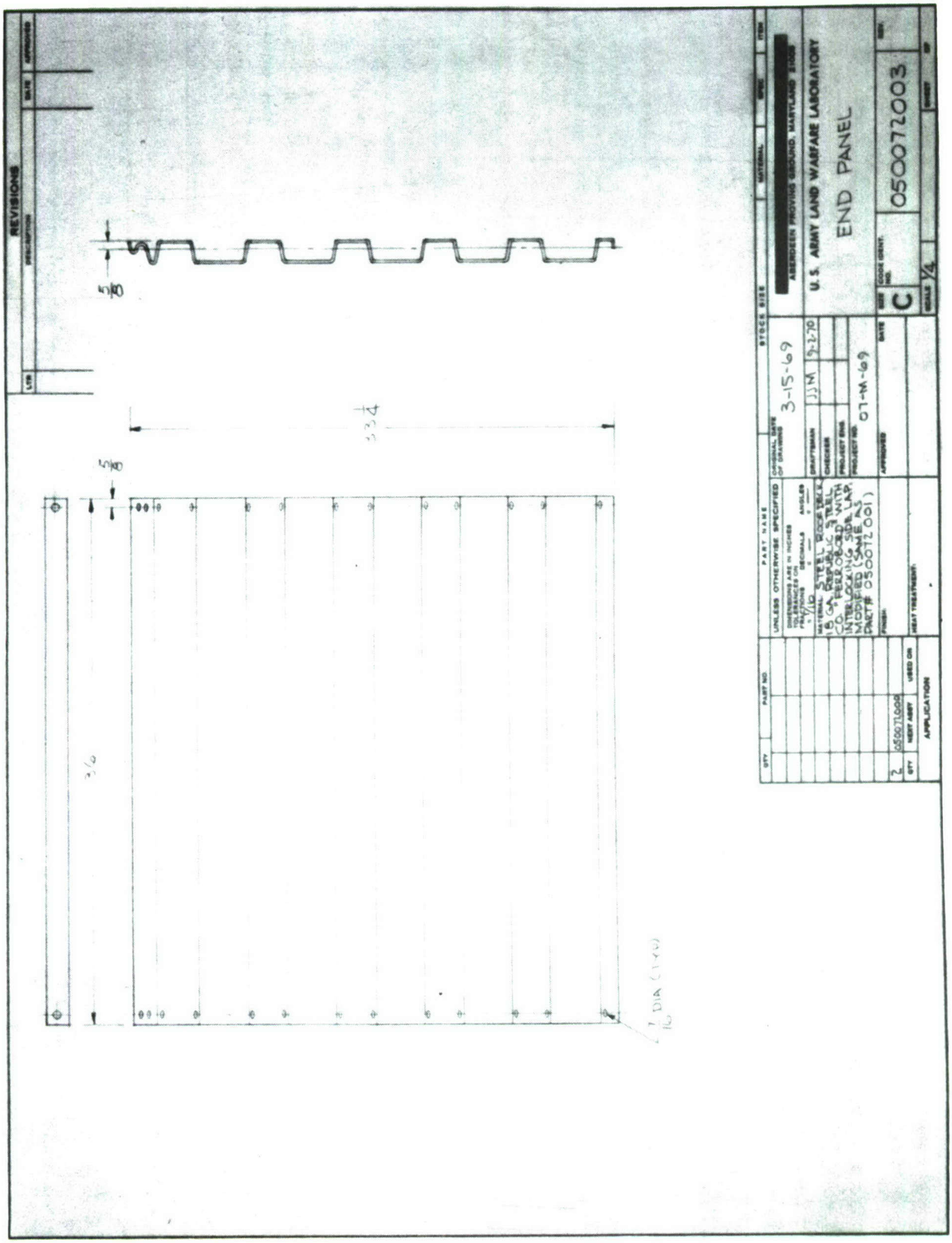
FULL SCALE
18 GA. STEEL ROOF DECK
CO. "FEDERORD"
WITH INTERLOCKING
SIDE LAP
3-15-69
J.M.
07-M-69
U.S. ARMY LAND WARFARE LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005
ROOF PANEL
D
05007Z004
APPLICATION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DESCRIPTION
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QTY
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PART NAME
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FINISH
HEAT TREATMENT
ORIGINAL DATE OF DRAWING 3-15-69
DRAFTSMAN JJM 9-2-70
CHECKER
PROJECT ENG.
PROJECT NO. 07-M-69
APPROVED
DATE
STOCK SIZE
MATERIAL
SPEC
ITEM
[redacted]
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REV
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SHEET OF
2
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NEXT ASSY
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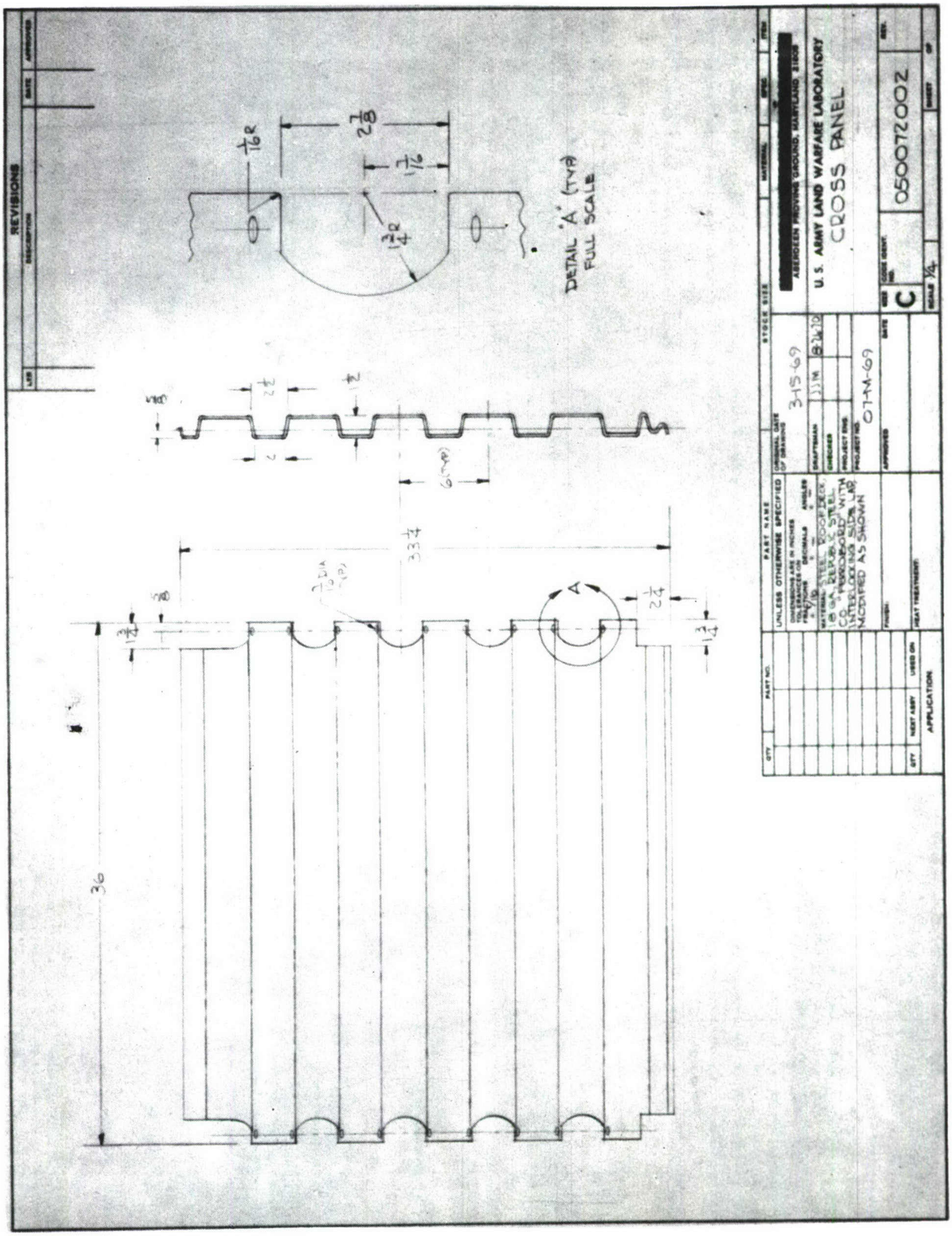
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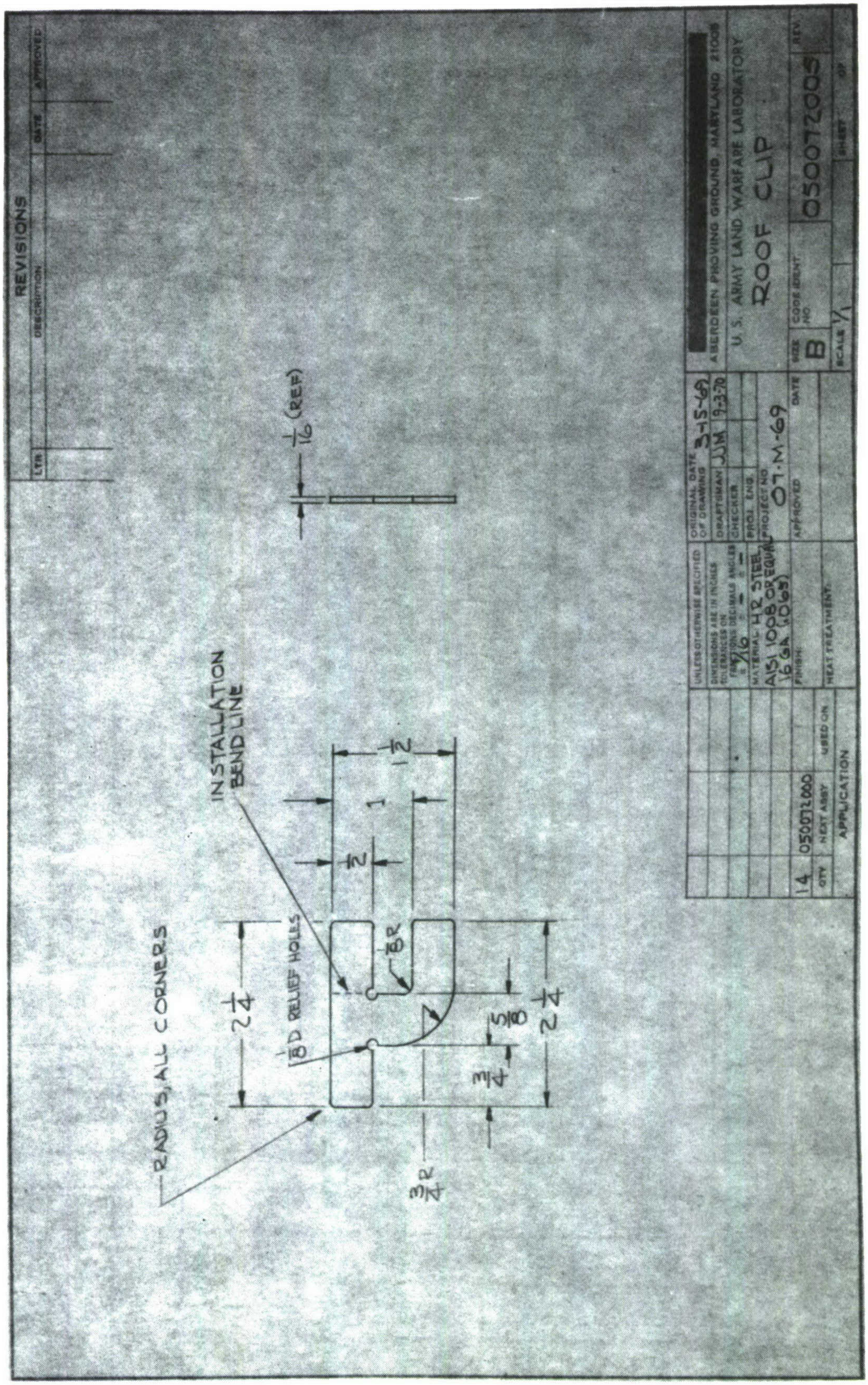
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DESCRIPTION
DATE
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1
1 1/2
1/8 R
3/4 R
3/4
5/8
2 1/4
1/16 (REF)
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
± 1/16
MATERIAL H.R. STEEL AISI 1008 OR EQUAL 16 GA (.065)
FINISH:
HEAT TREATMENT:
ORIGINAL DATE OF DRAWING 3-15-69
DRAFTSMAN JJM 9-3-70
CHECKER
PROJ. ENG.
PROJECT NO. 07-M-69
APPROVED
DATE
[redacted]
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U. S. ARMY LAND WARFARE LABORATORY
ROOF CLIP
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SHEET
OF
14
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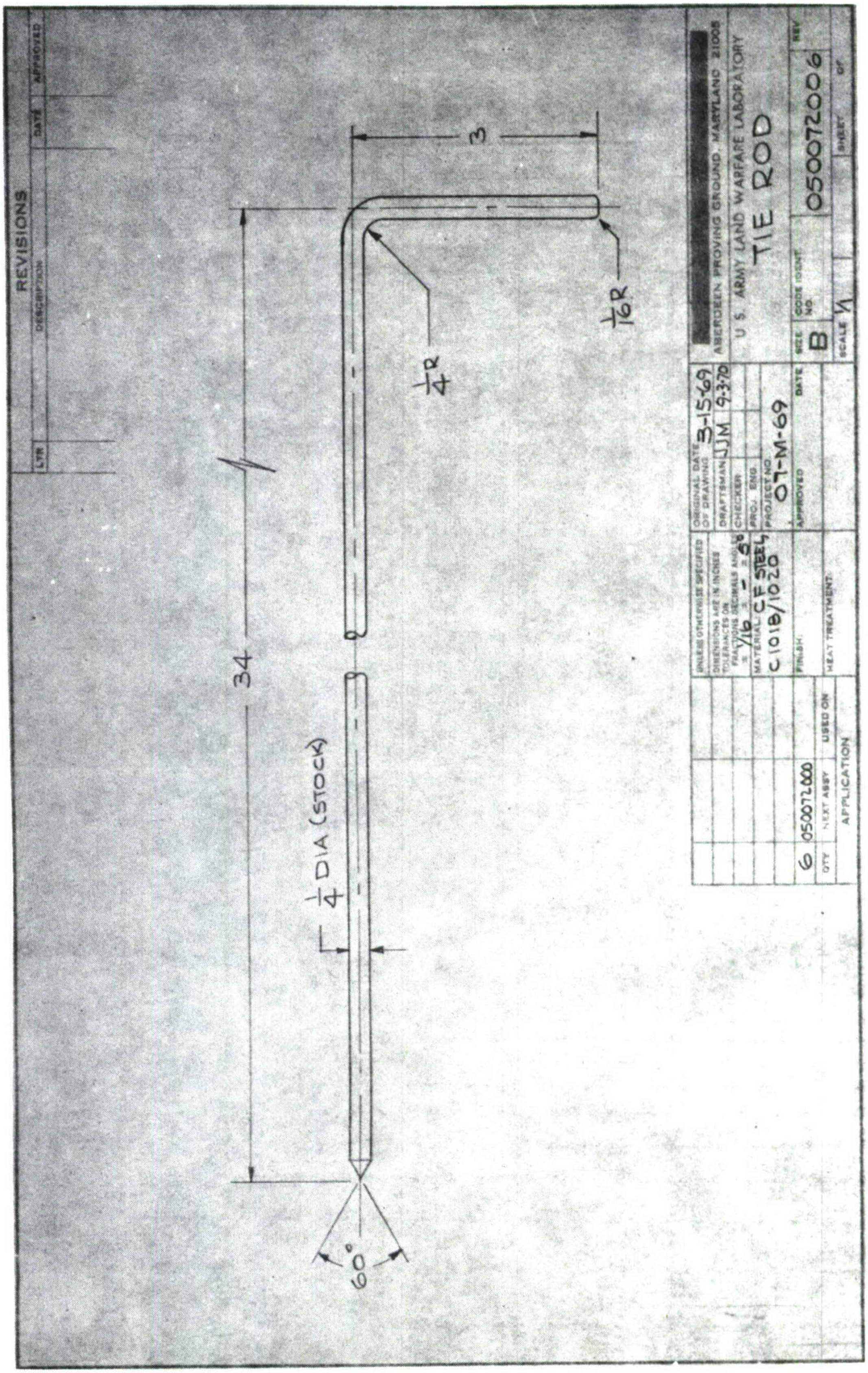
APPLICATION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DATE
APPROVED
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1/16 R
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1/4 DIA (STOCK)
60°
[redacted]
ABERDEEN PROVING GROUND, MARYLAND 21005
U.S. ARMY LAND WARFARE LABORATORY
TIE ROD
SIZE B
CODE IDENT NO
05007200 6
SCALE 1/1
SHEET OF
REV
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES ± 1/16
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ORIGINAL DATE OF DRAWING 3-15-69
DRAFTSMAN LJM 9-3-70
CHECKER
PROJ. ENG.
PROJECT NO. 07-M-69
APPROVED
DATE
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13. ABSTRACT

This study surveys existing revetments, work being done on revetments, design of general purpose revetments, and recommends a specific revetment design.

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