GRAPHIC SCALE

LEGEND

NOTES:

1. DRAWING DEVELOPED PER INFORMATION MCB-40, DWG NO. 40-69-005.

SYM	REVISION DESCRIPTION	BY	APPD	DATE

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

SEABEE SYSTEMS ENGINEERING OFFICE

U. S. NAVAL CONSTRUCTION BATTALION CENTER — PORT HUENEME, CALIFORNIA

ADVANCED BASE FUNCTIONAL COMPONENT

CAMP CAMPBELL

HUE (PHU BAI)

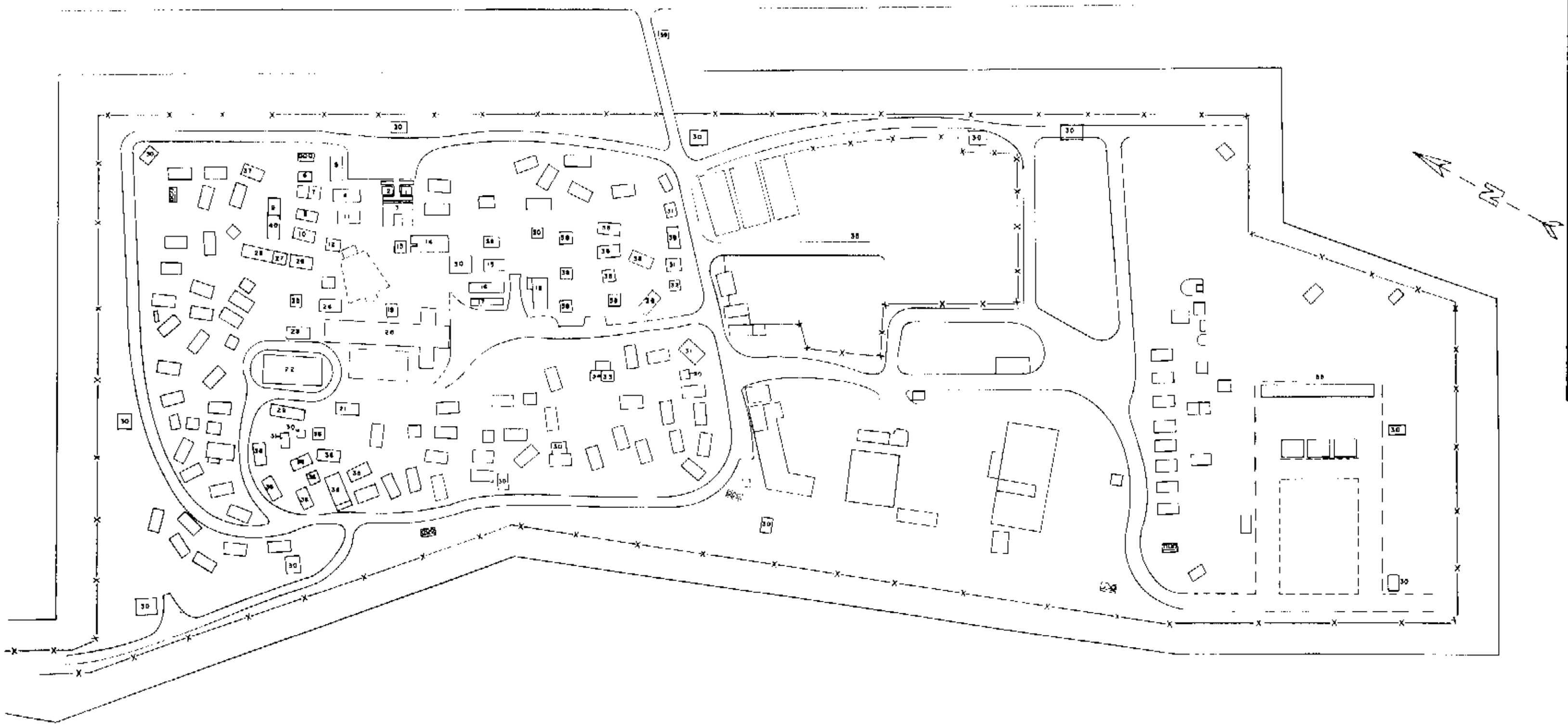
BY: A. Guerrero

APPROVED: FOR COMMANDER NAVFAC — DATE 9/4/69

CODE IDENT NO. 80091 | COMPONENT/ASSEMBLY | NAVFAC DRAWING NO. 1290726

SCALE: AS NOTED | SKETCH NO. 69-122 | SHEET OF

REFERENCE DWGS



LEGEND

NO.	DESCRIPTION
[illegible]	[illegible]

GRAPHIC SCALE

NOTES:
1. DRAWING DEVELOPED PER INFORMATION MCB - 4, DWG NO 6106

SYM	REVISION DESCRIPTION	BY	APPD	DATE

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

SEABEE SYSTEMS ENGINEERING OFFICE

U.S. NAVAL CONSTRUCTION BATTALION CENTER — PORT HUENEME, CALIFORNIA

ADVANCED BASE FUNCTIONAL COMPONENT

CAMP ADENIR

DA NANG-EAST

ARCH | ELEC | MECH

CHK

DR DWIGHT W JOHNSON 94-69

PROJECT MANAGER

DRAFTING SECTION

DESIGN SECTION

ENGINEERING BRANCH

ASST DIV DIRECTOR

DIVISION DIRECTOR

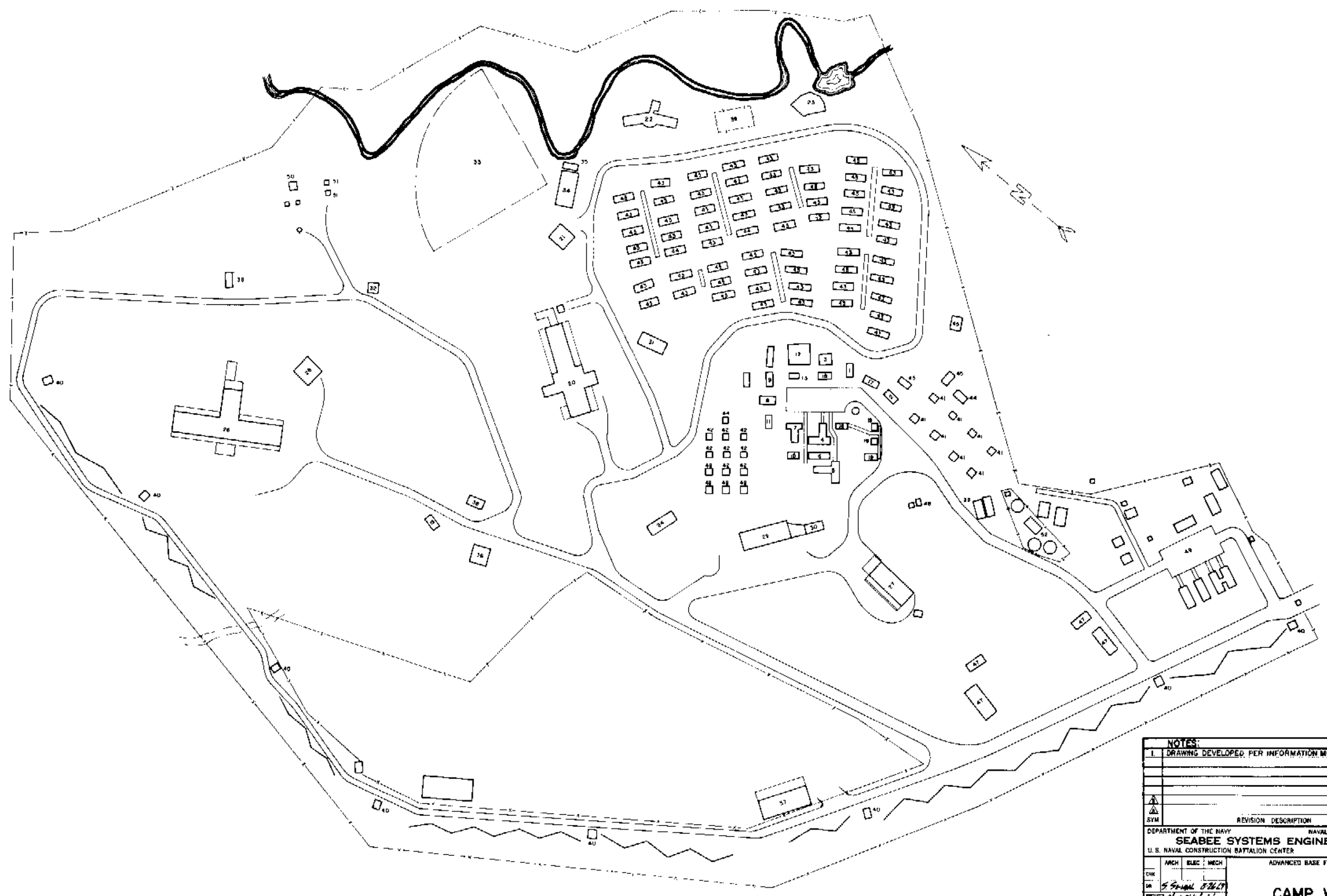
APPROVED — FOR COMMANDER NAVFAC — DATE 9/–/69

SATISFACTORY TO	CODE IDENT NO. 80091	COMPONENT-ASSEMBLY	NAVFAC DRAWING NO. 1209727
APPROVED / DATE	SCALE: AS NOTED	SKETCH NO. 69-123	SHEET OF

REFERENCE DWGS


LEGEND
NO.
DESCRIPTION
CAMP BARNES
CAMP SPILLMAN
GRAPHIC SCALE
NOTES:
1. DRAWING DEVELOPED PER INFORMATION MCB-62, DWG NO.RVN939I0907
SYM
REVISION DESCRIPTION
BY
APPD
DATE
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U. S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ARCH
ELEC
MECH
ADVANCED BASE FUNCTIONAL COMPONENT
CAMP BARNES,
CAMP SPILLMAN
DONG HA
APPROVED
FOR COMMANDER NAVFAC
DATE
SATISFACTORY TO
APPROVED
DATE
CODE IDENT NO. 80091
COMPONENT-ASSEMBLY
NAVFAC DRAWING NO. 1290728
SCALE: AS NOTED
SKETCH NO. 69-124
SHEET
OF
REFERENCE DWGS

107



LEGEND	
NO.	DESCRIPTION
1	[illegible]
2	[illegible]
3	[illegible]
4	[illegible]
5	[illegible]
6	[illegible]
7	[illegible]
8	[illegible]
9	[illegible]
10	[illegible]
11	[illegible]
12	[illegible]
13	[illegible]
14	[illegible]
15	[illegible]
16	[illegible]
17	[illegible]
18	[illegible]
19	[illegible]
20	[illegible]
21	[illegible]
22	[illegible]
23	[illegible]
24	[illegible]
25	[illegible]
26	[illegible]
27	[illegible]
28	[illegible]
29	[illegible]
30	[illegible]
31	[illegible]
32	[illegible]
33	[illegible]
34	[illegible]
35	[illegible]
36	[illegible]
37	[illegible]
38	[illegible]
39	[illegible]
40	[illegible]
41	[illegible]
42	[illegible]
43	[illegible]
44	[illegible]
45	[illegible]
46	[illegible]
47	[illegible]
48	[illegible]
49	[illegible]
50	[illegible]
51	[illegible]
52	[illegible]

NOTES:

1. DRAWING DEVELOPED PER INFORMATION MCB-[illegible] DWG NO. [illegible]-0069-050

SYM	REVISION DESCRIPTION	BY	APPD	DATE

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

SEABEE SYSTEMS ENGINEERING OFFICE

U. S. NAVAL CONSTRUCTION BATTALION CENTER — PORT HUENEME, CALIFORNIA

ADVANCED BASE FUNCTIONAL COMPONENT

CAMP WILKINSON

HUE (PHU BAI)

ARCH | ELEC | MECH

CHK

DR S. Seigal 8-26-69

PROJECT MANAGER

DRAFTING SECTION

DESIGN SECTION

ENGINEERING BRANCH

ASST DIV DIRECTOR

DIVISION DIRECTOR

APPROVED W. T. Bandel FOR COMMANDER NAVFAC — DATE 9/16/69

SATISFACTORY TO — APPROVED — DATE

COML IDENT NO. 80091

SCALE: AS NOTED

COMPONENT - ASSEMBLY

SKETCH NO. 69-125

NAVFAC DRAWING NO. 1290729

SHEET OF

REFERENCE DWGS

LEGEND

NO.	DESCRIPTION
1	[illegible]
2	[illegible] COMMAND POST
3	PHOTO LAB
4	CHAPLAIN/[illegible]
5	[illegible]/BARBER
6	SPECIAL SERVICES
7	CHAPEL
8	SICKBAY
9	ALT. COMMAND POST
10	POST OFFICE
11	EXCHANGE
12	[illegible] SURVEY
13	[illegible]
14	[illegible]
15	S-1
16	S-2
17	S-3
18	S-4
19	[illegible] OFFICES
20	[illegible]
21	[illegible]
22	[illegible]
23	[illegible]
24	[illegible]
25	[illegible]
26	[illegible]
27	[illegible]
28	[illegible]
29	[illegible]
30	[illegible]
31	[illegible]
32	[illegible]
33	[illegible]
34	[illegible]
35	[illegible]
36	[illegible]
37	[illegible]
38	[illegible]
39	[illegible]
40	[illegible]

NOTES:

1. DRAWING DEVELOPED PER INFORMATION MCB-128 DWG NO. 11-002-1D

SYM	REVISION DESCRIPTION	BY	APPD	DATE
B				
A				

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

SEABEE SYSTEMS ENGINEERING OFFICE

U.S. NAVAL CONSTRUCTION BATTALION CENTER — PORT HUENEME, CALIFORNIA

ADVANCED BASE FUNCTIONAL COMPONENT

CAMP RHODES

QUANG TRI

DR: J. Gomez 8-25-69

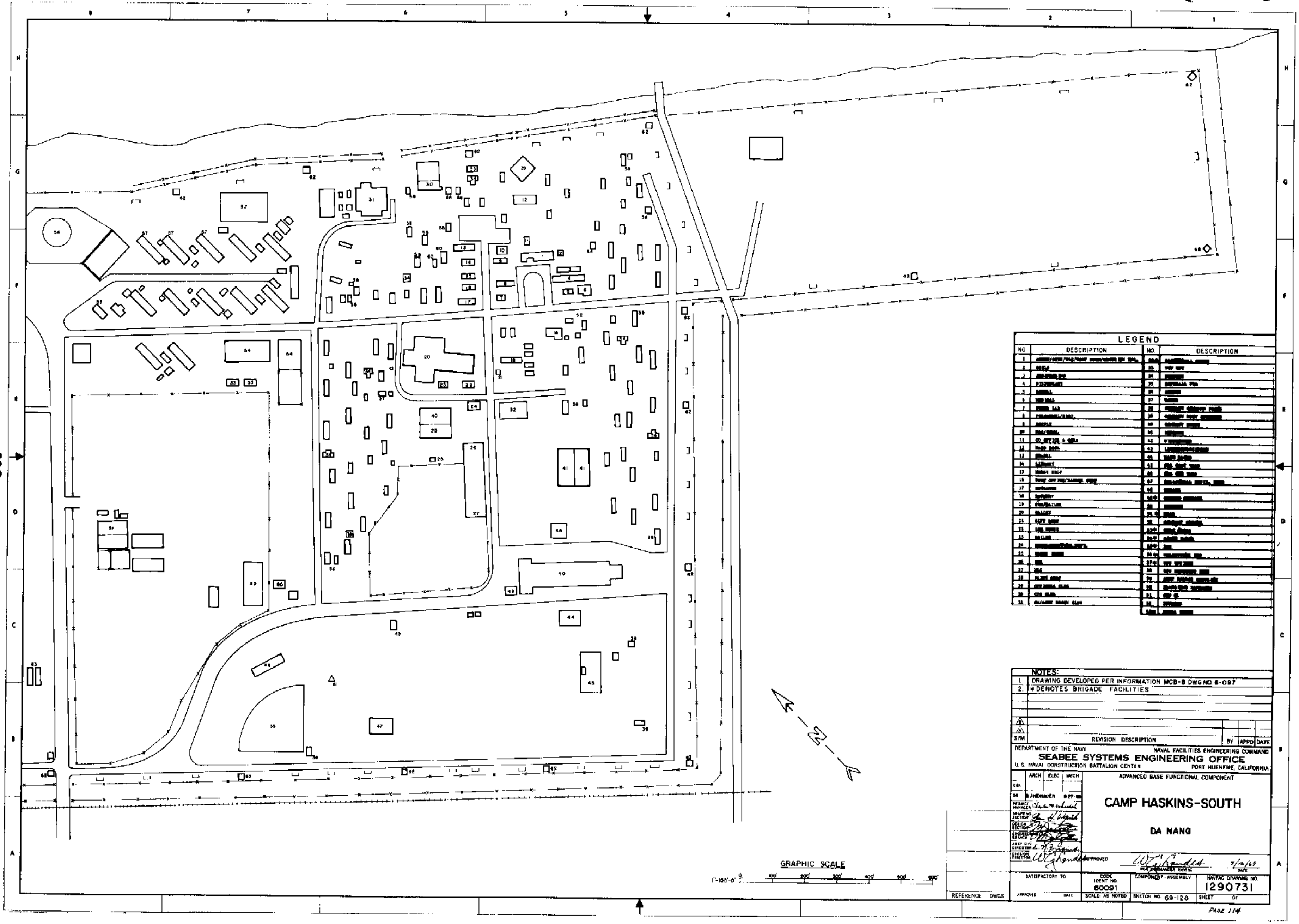
APPROVED: [signature] FOR COMMANDER NAVFAC — DATE 9/16/69

SATISFACTORY TO — APPROVED — DATE

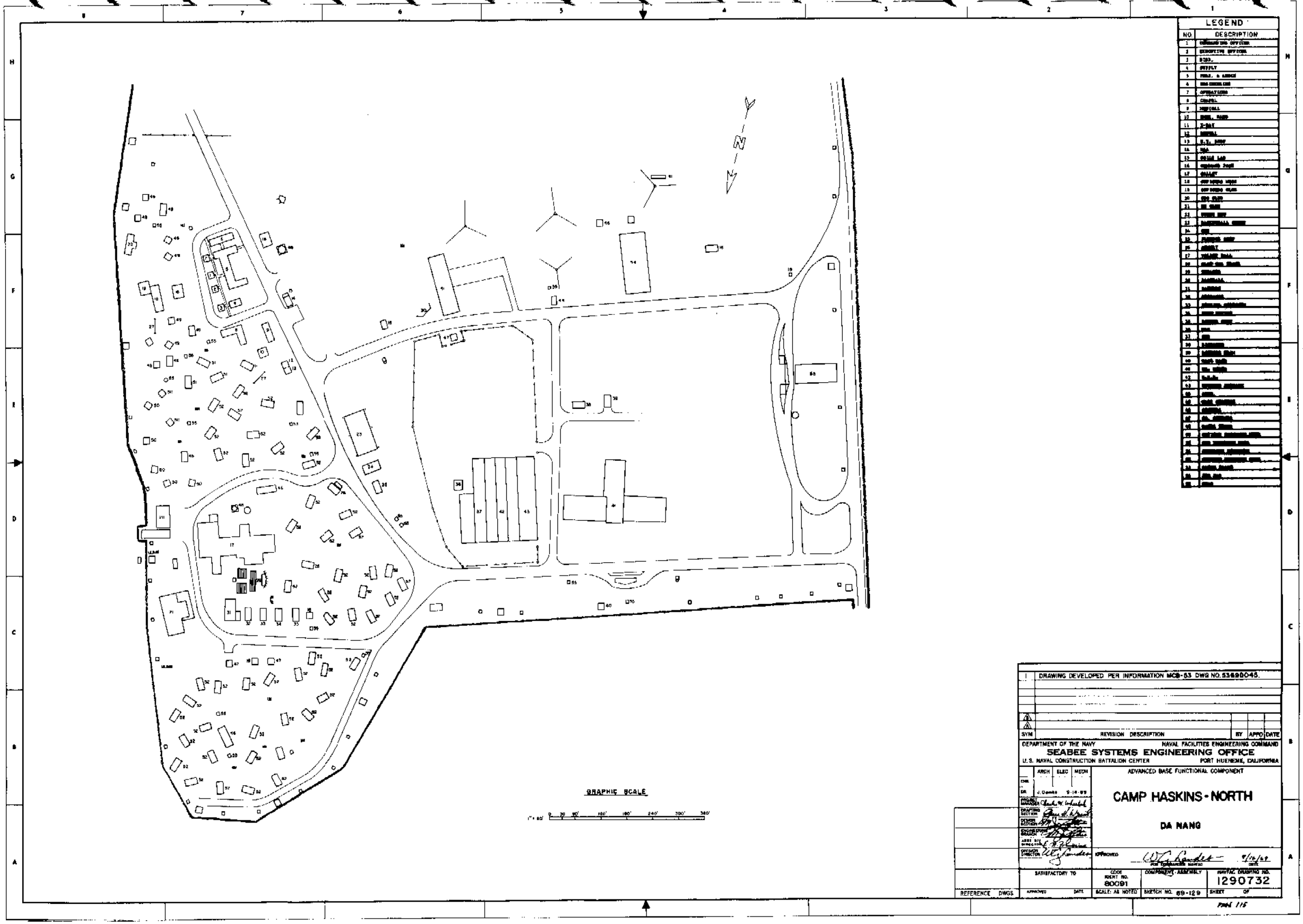
CODE IDENT NO 80091 | COMPONENT-ASSEMBLY | NAVFAC DRAWING NO. 1290730

SCALE: AS NOTED | SKETCH NO 69-128 | SHEET OF

REFERENCE DWGS

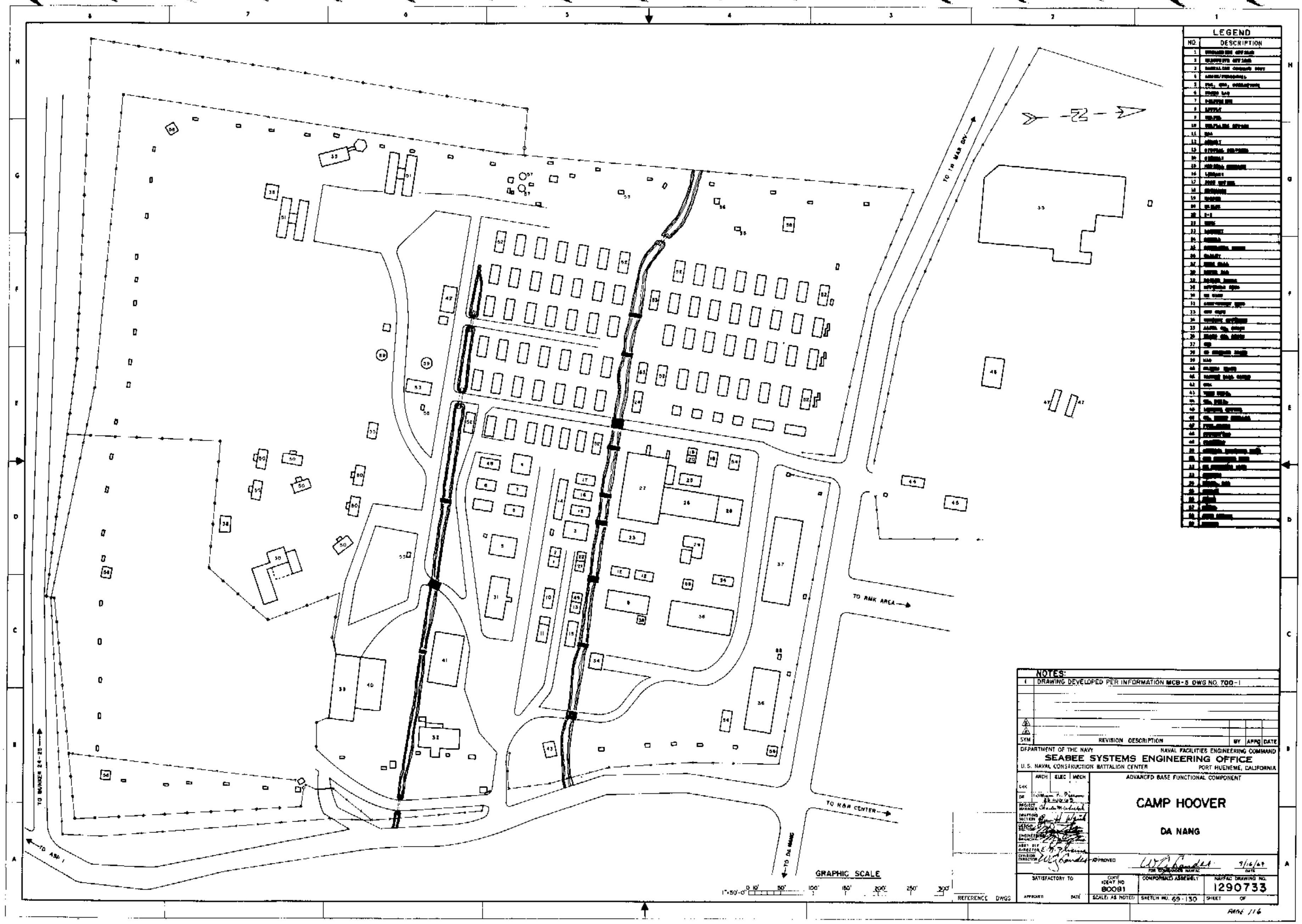

LEGEND
NO. DESCRIPTION
NOTES:
1. DRAWING DEVELOPED PER INFORMATION MCB-8 DWG NO. 8-097
2. * DENOTES BRIGADE FACILITIES
SYM REVISION DESCRIPTION BY APPD DATE
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U. S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ADVANCED BASE FUNCTIONAL COMPONENT
CAMP HASKINS-SOUTH
DA NANG
APPROVED
DATE
SATISFACTORY TO
CODE IDENT NO. 60091
COMPONENT - ASSEMBLY
NAVFAC DRAWING NO. 1290731
SCALE: AS NOTED
SKETCH NO. 69-128
SHEET OF
REFERENCE DWGS
GRAPHIC SCALE
N

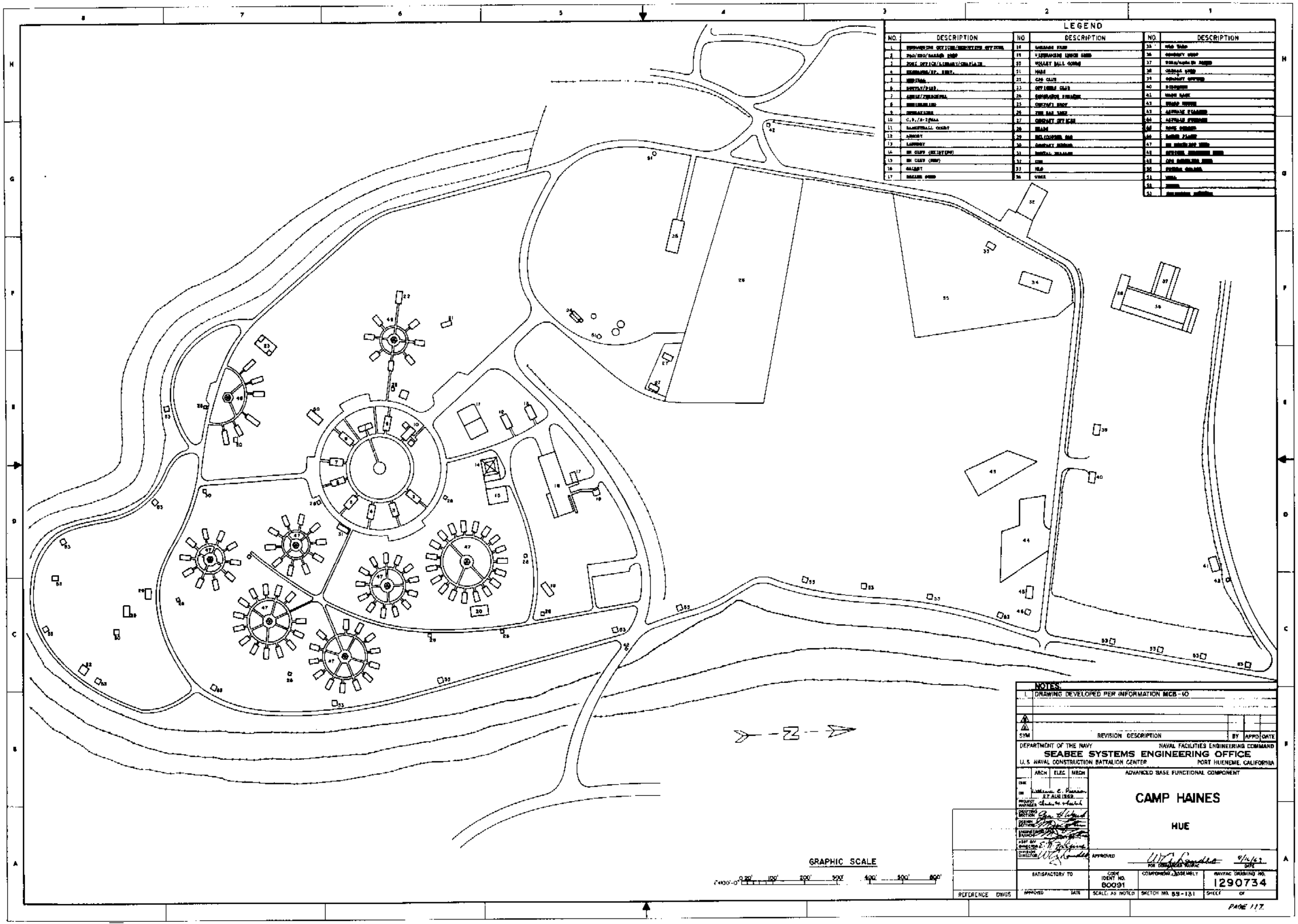
115



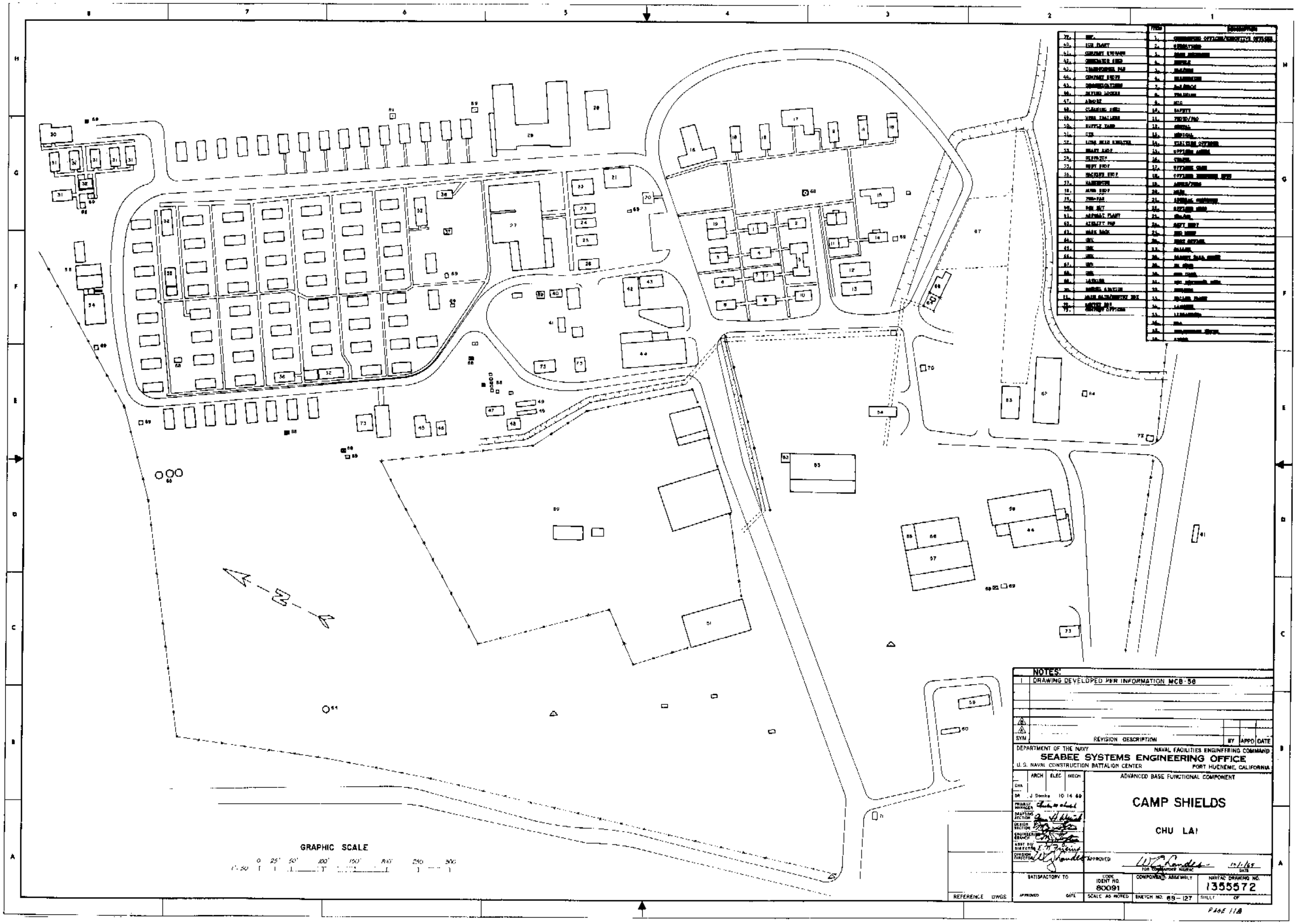
LEGEND
NO.
DESCRIPTION
GRAPHIC SCALE
1" = 80'
0 20 40 80 120 160 240 320 360
DRAWING DEVELOPED PER INFORMATION MCB-63 DWG NO. 53690045.
SYM
REVISION DESCRIPTION
BY
APPD
DATE
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U.S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ARCH
ELEC
MECH
ADVANCED BASE FUNCTIONAL COMPONENT
CAMP HASKINS - NORTH
DA NANG
APPROVED
SATISFACTORY TO
CODE IDENT NO. 80091
COMPONENT - ASSEMBLY
NAVFAC DRAWING NO. 1290732
REFERENCE DWGS
APPROVED
DATE
SCALE: AS NOTED
SKETCH NO. 69-129
SHEET
OF

Page 115


LEGEND
NO. DESCRIPTION
TO 1st MAR DIV
N
TO RMK AREA
TO R&R CENTER
TO DA NANG
TO BUNKER 24-25
TO ASP 1
GRAPHIC SCALE
1"=50'-0"
0 10' 50' 100' 150' 200' 250' 300'
REFERENCE DWGS
NOTES:
1 DRAWING DEVELOPED PER INFORMATION MCB-5 DWG NO. 700-1
SYM REVISION DESCRIPTION BY APPD DATE
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U.S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ARCH ELEC MECH
CHK
DR
PROJECT MANAGER
DRAFTING SECTION
DESIGN SECTION
ENGINEERING BRANCH
ASST DIV DIRECTOR
DIVISION DIRECTOR
ADVANCED BASE FUNCTIONAL COMPONENT
CAMP HOOVER
DA NANG
APPROVED
FOR COMMANDER NAVFAC
9/16/69
DATE
SATISFACTORY TO
APPROVED DATE
CODE IDENT NO
80091
COMPONENT ASSEMBLY
NAVFAC DRAWING NO.
1290733
SCALE: AS NOTED
SKETCH NO. 69-130
SHEET OF



NO.	DESCRIPTION	NO	DESCRIPTION	NO.	DESCRIPTION
1	[illegible]	18	[illegible]	35	[illegible]
2	[illegible]	19	[illegible]	36	[illegible]
3	[illegible]	20	VOLLEY BALL COURT	37	[illegible]
4	[illegible]	21	[illegible]	38	[illegible]
5	[illegible]	22	CPO CLUB	39	[illegible]
6	[illegible]	23	OFFICERS CLUB	40	[illegible]
7	[illegible]	24	[illegible]	41	[illegible]
8	[illegible]	25	[illegible]	42	[illegible]
9	[illegible]	26	[illegible]	43	[illegible]
10	[illegible]	27	[illegible]	44	[illegible]
11	BASKETBALL COURT	28	[illegible]	45	[illegible]
12	ARMORY	29	[illegible]	46	[illegible]
13	LAUNDRY	30	[illegible]	47	[illegible]
14	[illegible]	31	[illegible]	48	[illegible]
15	[illegible]	32	[illegible]	49	[illegible]
16	GALLEY	33	[illegible]	50	[illegible]
17	[illegible]	34	[illegible]	51	[illegible]
				52	[illegible]
				53	[illegible]



GRAPHIC SCALE
NOTES:
1. DRAWING DEVELOPED PER INFORMATION MCB 58
REVISION DESCRIPTION
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U.S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ADVANCED BASE FUNCTIONAL COMPONENT
CAMP SHIELDS
CHU LAI
APPROVED
SATISFACTORY TO
CODE IDENT NO. 80091
COMPONENT ASSEMBLY
NAVFAC DRAWING NO. 1355572
SKETCH NO. 69-127
REFERENCE DWGS

NAVAL CONSTRUCTION BATTALION CENTER

PORT HUENEME, CALIFORNIA 93043

IN REPLY REFER TO.
155/GEK/11p
SERIAL 2113
12 April 1972

From: Commanding Officer, Naval Construction Battalion Center, Port Hueneme, California 93043
To: Distribution List

Subj: Lessons Learned Manual, NAVFAC P-399; updating of

Encl: (1) Revised page v for P-399
(2) New pages 122 through 142

1. The Lessons Learned Manual was published in October 1970 by the Seabee Support and Equipment Office. Enclosures (1) and (2) comprise the initial updating of this publication. It is intended that additional updatings will be published annually.

2. It is requested that enclosure (1) be substituted for the present page v, and that pages 122 through 142 be added to the P-399.

3. Any comments or recommendations for improvement of this publication should be forwarded to:

Commanding Officer
Naval Construction Battalion Center
Seabee Support and Equipment Office (Code 1533)
Port Hueneme, California 93043

G. E. KRAUTER
By direction

Distribution List:
SNDL 39B
SNDL 39C
SNDL 39D
SNDL 39E
SNDL 39G
SNDL 39I
SNDL FJ21
SNDL FJ28
SNDL FKA1C (Code 06)
SNDL FKN2
NRTC, Omaha
NCEL
RMCB-2
RMCB-12 thru 28
RNCR-1 thru 9
CBU-415

APPENDIX C

CORAL AGGREGATE IN A/C PAVEMENT AND CONCRETE CONSTRUCTION

ABSTRACT

The material presented herein is compiled from sources currently making use of coral for asphaltic concrete pavements and portland cement concrete construction, and from records of the Naval Construction Force. The intent is to indicate the important considerations and current pertinent data to enable responsible personnel of the Naval Construction Force to carry out their tasks without undue delay or difficulties.

ACKNOWLEDGEMENTS

Material and data for this document were received from a number of individuals and organizations, whose contributions are acknowledged with thanks. Among contributors were: D. L. Narver, Jr.. Holmes and Narver, Inc.; Frank D. Bates, manager Technical Services, and C. A. Boyce, project engineer, Pacific Test Division, Holmes and Narver, Inc.; William R. Lorman, research materials engineer, Naval Civil Engineering Laboratory; and OICC Marianas. Material contained in Appendix C was compiled by Balys (Bill) Ciurlionis, P.E., general engineer, Seabee Support and Equipment Office.

INTRODUCTION

The use of coral aggregate for concrete construction and A/C paving presents the designer/builder with unique problems. Since coral is the only aggregate material available in sufficient volumes at many remote island locations, the builder must become aware of its peculiarities and adapt his mix designs to them.

Fortunately, considerable experience has been accumulated and research conducted to provide today's engineer with a basic knowledge of the uses of coral aggregate and enable him to contend with its use with fewer problems than those faced by his predecessor.

These notes are compiled in order to bring this experience and research to a focus. The information, from a variety of authoritative sources, is presented without analysis or attempt at final evaluation; it is believed to reflect the usable experience and data through which the engineer can evolve methods to resolve his own problems involving the use of coral aggregate on his projects.

In the application of coral aggregate as a component of asphaltic concrete for road building or of concrete for construction, comprehensive and current knowledge is possessed by OICC, Naval Facilities Engineering Command, Contracts, Marianas, insofar as military organizations are concerned. Parallel mastery of coral pavements is possessed by Holmes and Narver, Inc., engineers and constructors who have served as contractors for military construction at Johnston Atoll, Christmas Islands and other Pacific islands. Much of the following information has been extracted from information provided by these sources.

OICC MARIANAS EXPERIENCE

Current knowledge regarding the use of coral aggregate in concrete for structures and asphaltic concrete mix for paved roads includes the following information and requirements of OICC Marianas. It must be emphasized that the charts showing typical mix designs are only suitable for use with aggregate from the Hawaiian Rock Products quarry and plants on Guam; coral from different pits, even on Guam, may require different designs. Other precautions and special considerations include: deficiencies in concrete that may result from low quality coral; haphazard grading; inferior placing; improper curing; and free moisture variation as much as 10% during any 15-minute interval due to intermittent showers, solar heat and high relative humidity. Fresh water supplies for washing and wet-screening may create problems. With A/G paving, heavy rains may wash off primer.

Production rates for concrete average 80 cubic yards per hour at Guam and 30 cubic yards at Saipan. Asphalt production rates are 100-120 tons per hour at Guam and 50 tons per hour at Saipan.

Table C-1 shows the design data for one of a series of designs of coral concrete formulated by personnel of OICC Marianas.

Coral Aggregate for Concrete Mix in Marianas

Aggregate used for coral concrete in the Marianas is manufactured from a massive white compact re-crystallized limestone that forms the Reef Facies of the Marianas limestone formation. The specific gravity of the limestone ranges from 2.52 to 2.64, absorption varies from 0.5 to 1.8 percent, and the average Los Angeles loss is 25 percent. When processed with jaw and roll-type crushing equipment, a deficiency usually exists in the No. 50 sieve size particles and a surplus of rock flour (minus No. 200 sieve size) is present. Grading deficiencies must be corrected by washing and/or by the addition of material procured from natural deposits of sand. Inasmuch as the "coral" of the Marianas embraces several types, the majority of which are not suitable for high-grade structural concrete, the various types encountered are given below, together with comments upon their properties:

a. Reef coral designates the geologically young coral materials usually found attached to the top and upper sloping faces of growing reefs. In-place reef coral provides a firm to hard structural foundation. It also provides considerably difficulty due to non-uniformity and irregular configuration of the surface. Piles may penetrate several feet of firm reef coral and then plunge into a large clay-filled cavity. Piles may reach bearing at widely varying depths only a few feet apart. Processed reef coral is satisfactory, when properly graded, for intermediate or low-grade concrete.

Table C-I - Coral Concrete Mix Design Calculations - Guam, Marianas Islands*

Design Strength (PSI)	WATER-CEMENT PASTE: CEMENT: Sack (per yd^3)	Weight (lbs)	Volume (ft^3)	WATER: Amount (gals)	Weight (lbs)	Volume (ft^3)	Water/ Cement Ratio	Volume of Paste (ft^3)
1500	3.85	361.9	1.84	35	291.55	4.67	9.0	6.51
2000	4.2	394.8	2.01	35	291.55	4.67	8.25	6.68
2500	4.8	451.2	2.29	35	291.55	4.67	7.25	6.96
3000	5.3	498.2	2.53	33	274.89	4.41	6.25	6.94
3500	6.0	564.0	2.87	33	274.89	4.41	5.5	7.28
4000	6.6	620.4	3.15	33	274.89	4.41	5.0	7.56
5000	8.7	817.8	4.16	33	274.89	4.41	3.75	8.57
6000	8.25****	775.5	3.94	33	274.89	4.41	4.0	8.37

**** With 2 ounces of Plastiment, a retarding densifier, per sack of cement.

Date of Calculations: 1 July 1969
All Volumes shown are absolute.
Bulk Specific Gravity of Cement: 3.15
Bulk SSD** Specific Gravity of coarse aggregate: 1" size = 2.53, corresponding to an absolute density of 157.87 pounds/cubic foot.
5/8" size = 2.55, corresponding to an absolute density of 159.12 pounds/cubic foot.
Bulk SSD Specific Gravity of fine aggregate--WMS***: 2.62, corresponding to an absolute density of 163.49 pounds/cubic foot.
Specific gravity of water: 1.00
Weight of one cubic foot of water: 62.4 pounds
Weight of water, pounds per gallon: 8.33
Weight of cement, pounds per sack: 94

**SSD - Saturated surface dry.
***WMS - Washed Marianas sand.
*Source: OICC Marianas

Design Strength (PSI)	Vol. of Aggr. (ft^3)	FINE AGGREGATES: Prop. of Aggr. Vol. %	Net Vol. (ft^3)	Net Wgt. (lbs)	COARSE AGGREGATES: Prop. of Aggr. Vol. %	Net Vol. (ft^3)	5/8" SIZE: Prop. of Coarse Aggr %	Vol. of 5/8" Size (ft^3)	Total Wgt (lbs)	1" SIZE: Prop. of Coarse Aggr %	Vol. of 1" Size (ft^3)	Total Wgt. (lbs)	BATCH WEIGHT: Unit Lbs/Ft^3	TOTAL
1500	20.49	47	9.63	1574	53	10.86	60	6.52	1037	40	4.34	685	146.25	3949
2000	20.32	46	9.35	1529	54	10.97	60	6.58	1047	40	4.39	693	146.48	3955
2500	20.04	45	9.02	1475	55	11.02	60	6.61	1052	40	4.41	696	146.9	3966
3000	20.06	44	8.83	1444	56	11.23	60	6.74	1072	40	4.49	709	148.1	3998
3500	19.72	42	8.28	1354	58	11.44	60	6.86	1092	40	4.58	723	148.4	4008
4000	19.44	42	8.17	1336	58	11.27	60	6.76	1076	40	4.51	712	148.9	4019
5000	18.43	39	7.19	1175	61	11.24	60	6.74	1072	40	4.50	710	150	4050
6000	18.63	45	8.38	1370	55	10.25	85	8.71	1386	15	1.54	243	150	4051

b. Lagoon coral is similar to reef coral in composition but contains very few cemented fragments. It is obtained usually as a by-product of hydraulic dredging. It is found in lagoons mixed with coral and volcanic sand and clay. Soft clayey lagoon coral may extend to considerable depths in large lagoons, so that major structures built thereon require extensive foundations. Dredging washes out most of the clay and pulverizes the softer coral particles. It is not suitable aggregate for any but low-grade concrete.

c. Reef sand, consisting mostly of disintegrated reef coral and small shells, is found along beach areas, in lagoons and in reef cavities. The sand has a uniform grading and a preponderance of flat particles that are structurally very weak. It can be used as a ballast material and as a fine aggregate for low- and intermediate-grade concrete.

d. Coralline limestone designates the geologically older, structurally sounder, reef-derived materials, making up much of the central mass of older reefs. It is dense, relatively pure limestone containing some dolomite and minor clay streaks. It has been altered by solution and subsequent recrystalization and is generally found in steep, high bluffs, elevated during the formation period of the island. Coralline limestone produces a very good hard aggregate, excellent for portland cement concrete. When used as an in-place foundation material, it provides a cavitated rock formation.

e. Cascajo, a term of Spanish origin meaning "gravelly coral" designates coral reef derived materials which occur in old deposits of shattered reef coral, lagoon sediments and reef talus. Cascajo consists of coral fragments with some residual sandy loam and is usually graded from silt sized particles to small boulders. Cascajo is the most abundant of coral reef-derived materials locally, and has had limited use as a source of aggregate for portland cement concrete, although generally, the cascajo particles are softer and structurally inferior to aggregate produced from "coralline limestone". The use of a particular cascajo depends on its physical properties; gradation, plasticity, bearing ratio, particle hardness, etc. As an in-place foundation material, cascajo varies from unacceptable to very good. Some of the deposits contain numerous pockets and seams of soft clay and small to large cavities that have been formed by the leaching out of the clay products, not readily discernible from surface reconnaissance, but determined only through extensive drilling. Use of the term cascajo is now being discouraged since the range of material covered is so wide. The term coral gravel modified with adjectives clayey, sandy, soft, compact, etc., is preferred. (Also see TR068).

Aggregate Requirements for the Marianas

Aggregate shall conform to the requirements of Paragraph 2.3, NAVDOCKS Specification 13Yh, modified as follows.

Fine aggregate for coral aggregate concrete in the Marianas shall be manufactured from coralline limestone having a specific gravity not less than 2.50. Approved natural sand may be used to supplement the fine aggregate manufactured from limestone. The natural and manufactured sands shall be blended in such proportions that the final gradation will be within the following limits:

Sieve Size	Percentage by Weight Passing Square Mesh Laboratory Sieves
3/8 inch	100
No. 4	95-100
No. 8	70-90
No. 16	45-75
No. 30	25-55
No. 50	10-30
No. 100	2-10
No. 200	0-5

The fine aggregate shall be free from injurious amounts of organic impurities and from material which might react harmfully with alkalies in the cement. The permissible amounts of deleterious substances shall be as given in Federal Specification SS-A-281b(3). Sampling and sieve analyses shall be made in accordance with Method Nos. 101.0 and 202.0, respectively, of Specification SS-R-406.

Coarse coral aggregate for concrete in the Marianas shall be manufactured from coralline limestone having a specific gravity not less than 2.50. Grading, methods of sampling, and testing shall be in accordance with Federal Specification SS-A-281 as specified therein for coarse aggregate. The abrasion loss shall be not more than 40 percent when the aggregate is tested in accordance with Federal Specification SS-R-406, Method No. 208.11.

Coarse aggregate of nominal size 1-1/2" to No. 4 shall be in two separate sizes: No. 4 to 3/4" and 3/4" to 1-1/2". Coarse aggregate for nominal size 1" to No. 4 shall be in two separate sizes: No. 4 to 1/2" and 1/2" to 1". The two separate sizes of coarse aggregate shall be combined at the proportioning plant in proportion by weight to product aggregates meeting the grading requirements specified above.

Proportioning - Coral-aggregate concrete in the Marianas shall conform to the requirements of NAVDOCKS Specification 13Yh, Table I for normal concrete with the exception that the minimum cement factor for Class C and D shall be reduced 0.25 bags per cubic yard, provided the specified strength can be obtained.

Batching - Close control is necessary for the production of suitable coral concrete. Volumetric batching cannot be successfully utilized and is not permitted.

Pavement

Portland Cement Concrete Roads and Runways - Have generally proved satisfactory in the Marianas area. Care must be taken to thoroughly dampen the subbase so as to prevent absorption of water from the freshly placed concrete. Available evidence indicates that the absorption of water from the freshly placed concrete may be more efficiently prevented by the use of a thin seal coat (0.3 gal. asphalt/yd^2) upon the prepared subbase rather than by attempting to dampen the porous coral.

Portland cement concrete pavement for airports shall be constructed in accordance with the provision of NAVDOCKS Specification 45Yd and 46Ye except as modified herein.

Coral Aggregates in A/C Pavements

Bituminous Roads, Runways, etc. - Plant mix hot-laid asphaltic concrete (5.5 to 6.5% asphalt) has been used successfully in the Marianas for roads, streets, runways, and taxiways. The aggregate used is a coralline limestone which, when crushed, develops a high percentage of minus 200-mesh material. When designing asphaltic concrete, allowance must be made for the asphalt absorbed within the internal voids of the aggregate, which does not contribute to the stability of the mix. Approximately 1% of asphalt cement is normally lost. The rate of oxidation of asphalt concrete pavements in the Marianas is extremely high. A light seal coat consisting of 0.10 0.15 gallons/yd^2 of RC-2 (rapid-curing liquid-asphaltic material) with a sand (100% passing the No. 8 sieve) cover coat should be applied to all runways immediately upon construction. Crushed stone "chips" should not be used as a cover coat due to the likelihood of particles being knocked loose and thrown into jet engines during formation take-offs. Runway areas that receive only light use should be subjected to periodic artificial traffic with a rubber-tired "wobbly" roller. Seal coats should be applied at more frequent intervals than is the practice in the continental United States.

OICC, Marianas specification for bituminous roads, streets, and parking areas should be used as a guide for all bituminous construction on Guam, except airfield pavement.

Road-mix asphalt pavement has been used in the Marianas for temporary access and low-cost secondary roads. Due primarily to the high percentage of minus 200-mesh material in the aggregate, the only asphalts that have been successfully used in road mixes have been medium-curing cutbacks (MC-2 and MC-3) or a slow-setting asphalt emulsion (SS-1). Pavements made in this manner have been mainly unsatisfactory due to low stability and are not recommended for use. Bituminous surface treatments have performed better than the road-mix asphalt, but are recommended for secondary roads only.

Coral Roads - Processed reef coral is satisfactory for stabilized second-class roads. Coralline limestone is excellent for base course and asphaltic concrete.

Sidewalks - Due to the high rate of oxidation encountered, portland cement concrete sidewalks are preferred over asphaltic concrete. Mildew and algae growth occur profusely on the walks in shaded areas. The sidewalk shall be scrubbed clean with a detergent and washed off with a 2 to 3% solution of calcium hypochlorite.

Parking Areas - Hot-mix asphaltic concrete has proved suitable for use in parking areas except around warehouses and docks where the area is subjected to traffic by hard-tired forklifts, dollies and trailers. In these areas, portland cement concrete pavement should be used. This recommendation is also applicable to warehouse floors, unless the underlying soil conditions are such that consolidation is expected. In such cases, asphaltic concrete should be used.

CIVILIAN CONTRACTOR EXPERIENCE

Holmes and Narver Inc. has used coral aggregate and asphalt mix for surface, binder and base courses on airport taxiways, roadways and miscellaneous stabilized areas at such typical locations as Johnston Atoll, Christmas Island and other Pacific islands, according to F. D. Bates, Manager, technical services, for Holmes and Narver's Pacific Test Division. He reports that the coral material is usually obtained by a form of dredging operation and stockpiled, and notes that in those areas where coral aggregate has been used, the concrete surfaces have been found to be stable after periods of from five to ten years. He emphasizes that the final determination of suitability of coral aggregate for various applications should be based on hardness and stability analyses.

Table C-II - Asphaltic Concrete Mixes with Coral Aggregate*
Guam, Marianas Islands

Bin No.	Proportion %	Weight (lbs)	Cumulative Weights (lbs)	Bin No.	Proportion %	Weight (lbs)	Cumulative Weights (lbs)
Fine Resurface				Regular Resurface			
2	25	1000	1000	2	25	1000	1000
3	20	800	1800	3	20	800	1800
4	5	200	2000	4	10	400	2200
1	50	2000	4000	1	45	1800	4000
Asphalt	5.875-6.0	235-240		Asphalt	5.75-5.875	230-235	
Driveway				Road Mix			
2	35	1400	1400	2	20	800	800
3	15	600	2000	3	25	1000	1800
1	50	2000	4000	4	10	400	2200
				1	45	1800	4000
Asphalt	6.0-6.25	240-250		Asphalt	5.75-5.875	230-235	
Oiled Sand Cushion Road				Tennis Court Mix			
2	35	1400	1400	2	40	1600	1600
1	65	2600	4000	1	60	2400	4000
Oil	4.25	170		Asphalt	5.66-5.89	240-250	

Aggregate Distribution By Bins

Sieve No.	1	3/4	1/2	#4	#10	#40	#80	#200
Bin No. 1				X	X	X	X	X
Bin No. 2			X	X	X	X	X	X
Bin No. 3		X	X	X	X	X	X	X
Bin No. 4	X	X	X	X	X	X		

Typical mix designs of asphaltic concrete with coral aggregate from a particular quarry on Guam. Aggregate for this plant is stocked in four bins with aggregate size ranges shown above.

*Source: OICC Marianas

One notable deficiency in most coral aggregates, Bates reports, is the absence of extreme fine grain particles. The mixing plants add cement to replace these sizes.

Tables C-111 and C-IV show data from a specific sampling program for Holmes and Narver's plant at a runway extension project on Johnston Island. Table C-III is a chemical and physical report on the particular hot mix design and Table IV summarizes the results of sieve tests of the coral binder material from cuts taken in the morning and the afternoon.

Table C-III - Hot Mix Design and Control Data -- Marshall Method*

Ring Specimen and Location	Computations and Test Value					
(1) Briquette Number	1	2	3	4	5	6
(2) % A/C by Wt. of Mix	5.5	5.5	5.5	5.5	5.5	5.5
(3) Height of Briquette (inches)	2-5/8	2-9/16	2-5/8	2-1/2	2-3/4	2-7/16
(4) Weight of Briquette (Air-grams)	1138.6	1117.0	1113.5	1163.8	1163.5	1042.7
(5) Weight of Briquette (Water-grams)	592.5	582.7	571.3	550.5	595.0	537.9
(6) Bulk Vol.=(4)-(5)	546.1	534.3	542.2	513.3	568.5	505.2
(7) Wt. of Aggregate (4)x(100 - % A/C)	1076.0	1055.6	1052.3	1005.3	1099.5	985.4
(8) Wt. of A/C=(4)-(7)	62.6	61.4	61.2	58.5	64.0	57.3
(9) Abs. Vol. Agg=(7)/G	461.8	453.0	451.6	431.5	471.9	422.9
(10) Abs. Vol. A/C=(8)/G	61.4	60.2	60.0	57.4	62.7	56.2
(11) Agg. Voids=(6)-(9)	84.3	81.3	90.6	81.8	96.6	82.3
(12) % Agg. Voids (11/(6)x100	15.4	15.2	16.7	15.9	17.0	16.3
(13) % Agg. Voids Filled (10)/(11)x100	72.8	74.0	66.2	70.2	64.9	68.3
(14) Bulk Density %(4)/(6)	2.085	2.091	2.054	2.072	2.047	2.064
(15) Theoretical Density $\frac{100}{(\%A)/G+(\%AC)/G}$	2.176	2.176	2.176	2.176	2.176	2.176
(16) % Theo. Density (14)/(15)x100	95.8	96.1	94.4	95.2	94.1	94.9
(17) % Voids in Comp. Mix 100-(16)	4.2	4.9	5.6	4.8	5.9	5.1
(18) Unit Wt.=(14)x62.4	130.1	130.5	128.2	129.3	127.7	128.8
(19) Marshall Stability	4812	4050	3550	2700	4417	3067
(20) Marshall Stability (Corrected)	4470	3890	3300	2700	3800	3190
(21) Flow	17	14	15	14	12	10

*Source: Holmes and Narver, Inc.

Table C-IV - Hot Mix Design and Control Data - Marshall Method*

Sieve tests of coral binder material samples as received from asphalt batch plant.

SIEVE SIZE	Bin No. 1 Fine Coral		Bin No. 2 Coarse Coral		Bin No. 3 Coarse Coral		Composite of Bins 1, 2 and 3	
	% Ret	% Pass	% Ret	% Pass	% Ret	% Pass	% Pass	Specifications
MORNING SAMPLE								
3"								
2"								
1-1/2"						100	100	
1"					25	75	90	75-95
3/4"				100	30	45		
1/2"			5	95	29	16	65	59-77
3/8"			11	84	13	3		
1/4" #3		100						
#4	2	98	84		2	1	44	39-55
#8					1			
#10	14	84					38	27-42
#16								
#20	19	65						
#40	17	48					22	13-23
#80	22	26					12	7-15
#100	3	23						
#200	7	16					7	3-7
PASS 200	16							
AFTERNOON SAMPLE								
3"								
2"								
1-1/2"						100	100	100
1"				100	19	81	80	75-95
3/4"			5	95	38	43		
1/2"			9	86	27	16	62	59-77
3/8"			15	71	12	4		
1/4", #3		100						
#4	2	98	71		4		44	39-55
#8								
#10	29	69					31	27-42
#16								
#20	24	45						
#40	13	32					14	13-23
#80	13	19					9	7-15
#100	2	17						
#200	6	11					5	3-7
PASS 200	11							

*Source: Holmes and Narver, Inc.

CORAL QUALITY

William R. Lorman of the Naval Civil Engineering Laboratory, Port Hueneme, California, in Technical Report 068 "Coral and Coral Concrete" summarized his findings from the study of techniques required to produce better quality coral mortars and concretes.

He concluded, with respect to coral concrete construction during peacetime, the most desirable aggregate is a coralline limestone possessing a structural quality rating greater than 65% sound material, determined by petrographical analysis.

From his studies of mix designs, Lorman presented the typical compressive strength values that should be expected with concrete incorporating quarry coral aggregate, as shown in Table C-V. The fines, representing 51% of the total aggregate, as shown in Table C-VI fall within the 50 to 60% range considered optimum for adequate mixes.

In Table C-VII Lorman shows results that can be expected when mixes are designed by volumetric proportioning. This method is necessitated when it is impractical to separate the fine and coarse portions of coral aggregate, as may be the case of bank run coral and insufficient or no screening equipment. The data shown in Table C-VII are valid when the maximum size of aggregate is 1-1/2". Lorman cautions that when mixes are designed on a volumetric basis using bank run coral, less water than is shown in Table C-V should be used initially.

Table C-V - Typical Mix Proportions (By Weight) For one Cubic Yard of Concrete Incorporating Typical Quarry Coral Aggregate**

28-day compressive strength (psi)	2000-3000	3000-4000	4000-5000
Cement Content (lb)	470	564	658
Coarse Aggregate (lb)	1600	1560	1460
Fine Aggregate (lb)	1540	1500	1400
Water, total (lb)	332	320	315
Slump (inches ± 1/2)	3	3	3
Coarse/Fine Ratio (by wt)	1.04	1.04	1.04
Aggregate/Cement Ratio (by wt)	6.7	5.4	4.3
Water/Cement Ratio (by wt)*	0.71	0.57	0.48

*Based upon net water content, assuming that aggregate is in saturated-surface dry condition at time of mixing.

**Source: NCEL TR068

Table C-VI - Mechanical Analysis of Nominal One-Inch Maximum Quarry Coral Aggregate Used in Concrete Mix Shown in Table C-V*

Size Designation	% Retained		Combined % Retained	
	Ind	Cum	Ind	Cum
1-1/2"	0	0	0	0
3/4"	10	10	5	5
3/8"	61	71	30	35
#4	29	100	14	49
FM	--	6.81	--	--
#4	0	0	0	--
#8	22	22	11	60
#16	20	42	10	70
#30	10	52	5	75
#50	14	66	7	82
#100	19	85	10	92
Pass 100	15	100	8	100
FM	--	3.67	--	5.68

Note: Unit Weight (of combined fine and coarse fractions) is 98 lb per cu. ft. (dry rodded).

FM denotes Fineness Modulus

Table C-VII - Typical Mix Proportions (By Volume) for One Cubic Yard of Concrete Incorporating Typical Bank-Run Coral Aggregate*

Aggregate-Cement Ratio by Vol.	Cement Content, sacks per cu. yd. Concrete	Gallons Water per sack Cement	Equivalent Water/Cement Ratio, by wt.	Slump, in.	Average Compressive Strength, psi 7-day	28-day
6	4.9	11.39	1.01	2	2100	2500
5	6.2	7.31	0.65	3	2900	3300
4	7.4	6.12	0.54	3	3700	4000
3	9.2	5.28	0.47	3	4200	4300

Note: Sand constitutes 50 percent of total aggregate. Maximum size of aggregate is 1-1/2 inches.

*Source: NCEL TR068

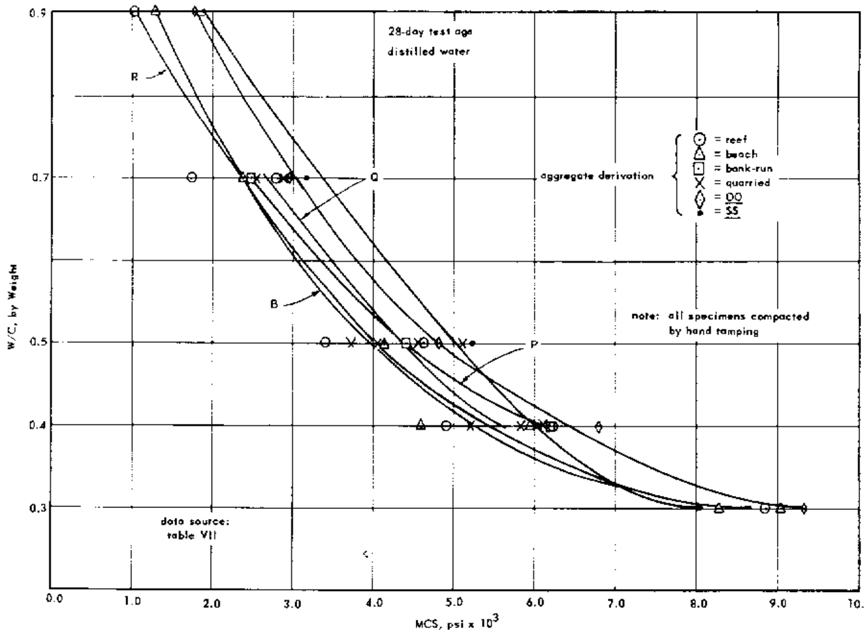
CORAL MORTARS

Lorman, in his studies to determine the physical properties of portland cement mortars incorporating coral sands, notes the fallibility of attempting to apply laboratory findings as a means of forecasting the general physical characteristics of mortars fabricated in the field. Most variables at the construction site can seldom be controlled; the accuracy of prediction decreases rapidly with the introduction of unavoidable unknowns. He also cites the general lack of technical expertise among the usual skilled construction worker directly engaged in fabricating and placing coral mortars.

He made 36 principal findings in testing nearly 2500 specimens to determine how and to what degree the physical characteristics of coral mortars are affected by physical factors.

After selected correlations were studied, interpretation of the resultant relationships led to general formulations that indicate the interdependence of mortar strength, elasticity, bulk density, volume change, weight change, air control, yield and flow.

Figure 1 - Typical Compression Strength Test Results of Mortars*



MCS denotes Modified Cube Strength.

*Source: Figure 89, based on Table C-VII of NCEL TR041.

Figure 1 typifies the nature of the testing as related to compressive strength of modified cubes made with reef, beach, bank-run and quarried coral sand and two reference sands, OO (sand from Ottawa, Illinois) and SS (San Gabriel River wash sand from Irwindale, California). This correlation shows that the variation of MCS (Modified Cube Strength) with W/C is approximately the same for all mortars investigated, regardless of water type, sand derivation or test age (not beyond one year). In nearly all cases the MCS value corresponding to a W/C of 0.3 is four to five times the MCS obtained when the W/C ratio is 0.9.

Of paramount significance among Lorman's principal findings are: (1) coral mortar yield is independent of sand derivation and type of mixing water, (2) coral mortars produced with reef sand and brackish water demonstrate the least volume change, (3) the type of water employed in the mix has no practical effect on the dynamic elastic modulus of the mortar, and (4) the nominal compressive strength of coral mortar is affected insignificantly by changing the derivation of natural-graded coral sand and increases with age irrespective of type of water used in the mix.

PERMEABILITY CONSIDERATIONS IN MIX DESIGN

The requirements for concrete possessing minimum permeability has been emphasized by Lorman in a technical report, "Permeability of Coral Concrete", where he describes the deterioration resulting from moisture and vapor penetration in the tropic environment; the development of cracks on the drier side of concrete walls which eventually spread and transmit to the wetter opposite face; and the corrosion of embedded steel reinforcement which results in spalling of the concrete cover.

After a year-long series of tests, Lorman developed recommendations and conclusions aimed at developing concrete mixes with minimum permeability to moisture, in liquid as well as vapor form. Among these recommendations, Lorman advisea to:

a. Use an aggregate gradation to insure a minimum of voids, with maximum particle size not exceeding one-fourth the thinnest concrete section;

b. Use a coarse/fine aggregate ratio that will produce a workable mix;

c. Use a gross water/cement ratio not greater than 0.44 by weight, equivalent to five gallons per bag of cement;

d. Use no less than eight bags of cement per cubic yard of concrete, or equivalent if pozzolan replaces part of the cement;

e. Transport and place the freshly-mixed concrete without segregation;

f. Compact the concrete completely by internal vibration, and externally when necessary; and

g. Cure the concrete under moist conditions at temperatures not higher than 90° F. for at least six weeks.

Lorman's tests and studies led him to the conclusion that rich mixtures are less permeable than lean mixtures; but no mixture is completely impermeable to water in the liquid or vapor state, due to the existence of capillaries in the hardened concrete and the imperfect bond between aggregate and paste. He noted that the less permeable concretes have higher compressive strength than the more permeable mixtures, regardless of the original quality of the aggregate.

Calcined Monterey shale, used as pozzolan to partially replace (usually 25% by volume) portland cement, makes coral concrete stronger, and more watertight and vaportight, all other factors being equal.

In summary, Lorman concluded that construction of watertight coral concrete requires a low-water/cement ratio, a high-cement factor, aggregate graded to minimize voids, very low slump, cohesiveness, complete compaction, practically no bleeding and long moist-curing.

Seawater in Coral Concrete Mixes

Impermeability takes on added importance when seawater is used for the concrete mix. John G. Dempsey, a construction engineer of Caparra Heights, Puerto Rico, described the use of seawater for coral concrete construction for the military bases built in the Bermuda Islands in World War II. He concluded that "seawater seems to be satisfactory for making reinforced concrete and develops no problem beyond an acceleration in stiffening of the fresh mix". He observed no harmful effect on the reinforced concrete after four years, but cautioned that corrosive action of any residual salts in the presence of air or moisture made it of paramount importance to take care to develop maximum density with resultant impermeability in the set concrete to assure durability.

EARLY EXPERIENCE WITH CORAL CONSTRUCTION

Construction of roads, airfields and other facilities on Guam in mid-1943 marked the most significant large-scale use of coral as a construction material to that time. Ample quantities of coral were available for construction according to Commodore W. O. Hiltabiddle, CEC, USN, Commanding Officer of the 5th U. S. Naval Construction Brigade. His organization directed all military construction on Guam during the invasion and subsequently built air bases and related facilities, a complex road system and the site of Admiral Nimitz' headquarters as Commander in Chief, Pacific.

. . . "Since Guam was to be developed as a major permanent base," said Hiltabiddle, "the Civil Engineers of the Fifth Naval Construction Brigade laid down rigid specifications. To allow for the oversize military vehicles, strips were planned to be wider than specifications set up under state-side standards. Main arteries were to be widened to 56 ft., super-elevated, and built to carry four 11 ft. lanes. Roads leading off the main highways would carry two or three lanes but no other criteria would be reduced. Turns on the roads were not to exceed 6 deg.; grades were to be held to a maximum of 6 per-cent; surfacing would be 2-1/2 in. of asphaltic concrete. The network was planned to total more than 100 miles of roads.". . .

. . . "Primary roads were surfaced with asphalt; secondary roads were surfaced with coral and then oiled." . . .

. . . "For the lighter roads, bank run "cascajo" was used; for the heavy-duty roads, crushed reef coral. Bulldozers, scrapers and rollers completed the surfacing, which was left unpaved". . .

In airfield construction, Naval Construction Battalion Forty joined with other units in constructing Bomber Field #3 at Luganville on Espiritu Santo, New Hebrides, used by the Army Air Corps for basing the B24's and B29's strikes on the Japanese-held islands. Extracts from the 18 August 1943 reports described the construction of one of the strips.

. . . "About the middle of June, grading and rough surfacing on the strip proper was complete, and the coral subgrade in place. The surface was then fine-graded and rolled; by the end of the month the surface was hard and smooth. Plans for using the Marston mat had to be abandoned, as operational experience in this area had proved it to be unsatisfactory, particularly as regards tire wear on fighter planes. Instead a bituminous asphalt emulsion, stabilized, surface was planned." . . .

. . . "After some initial experiments, on 6 July operations were begun to place the asphalt surface on the main runway. A 5% - 95% mixture of emulsion and water was distributed in two applications, and a 50% - 50% mixture on a third application. A setting period of about three days was allowed between successive coats. This part of the work was completed 16 July. This method produced a waterproof surface, but one that was too thin for the desired wearing qualities. A road mix, asphalt cover, using crushed coral as aggregate, is planned for the wearing surface." . . .

. . . "Construction operation, in the main part, has followed standard practice. The method for obtaining fine-graded coral for surfacing on the bomber strip is perhaps worthly of note. Carryalls were used to scrape the relatively soft material, without previous blasting or scarifying. The material thus obtained is fairly even-graded and is sufficiently fine for excellent fine-grading and rolling." . . .

REFERENCES

1. NCEL Technical Report 068, Coral and Coral Concrete, William R. Lorman, 13 April 1960.

2. NCEL Technical Report 041, Characteristics of Coral Mortars, William R. Lorman, 28 June 1960.

3. NCEL Technical Report 280, Permeability of Coral Concrete, William R. Lorman, 16 June 1964.

4. Paper 48-12, Proceedings of the American Concrete Institute, Vol. 48, pp. 157-168, Coral and Salt Water as Concrete Materials, John G. Dempsey 1952.

5. Letter from Frank D. Bates, Holmes and Narver, Inc. to Balys Ciurlionis, Seabee Systems Engineering Office (now Seabee Support and Equipment Office), Coral Aggregate and Asphalt Materials, 26 November 1969.

6. Letter from OICC (Officer in Charge of Construction) Marianas to Commanding Officer, Naval Construction Battalion Center, Port Hueneme, California, Coral Aggregate 5 December 1969.

7. W. O. Hiltabiddle, Jr., CEC, USN, Guam Superhighway Built in Sixty Days, Civil Engineering, May 1945.

8. Monthly Report, U. S. Naval Construction Battalion 40, 18 August 1943.

9. Monthly Report, U. S. Naval Construction Battalion 40, 9 September 1943.

Appendix D

HORTICULTURAL SOIL STABILIZATION

INTRODUCTION

The problems created by windborne sand and heavy rainfall are of considerable magnitude and of great military significance. The precisely machined tools of modern warfare (such as helicopters and jet aircraft) are ready prey to the onslaught of driving sand. The instability of uncovered soil endangers the foundations of extensive and expensive military installations. Blowing sand and erosion greatly interfere with the capability of individuals to perform military assignments as well as creating a serious morale problem.

First, one might question the frequent unnecessary removal of vegetation and then the subsequent lamentations about problems resulting from blowing sand. A second characteristic of this history is greatly influenced by the 1-year tour-of-duty system. When the problem is highly seasonal, a new arrival in the country may not be aware of the problem, and the men anticipating departure are frequently not concerned. Often projects initiated by an individual or group are not continued beyond the yearly period, or the attempted projects are not recorded, or the records are not passed on from year to year.

SOLUTION

To date, the principal methods of stabilizing soil are by applying soil-binding chemicals, crushed rock, asphalt, or sandbags, and by new construction. These methods are often dictated by military expediency and frequently are not intended to be of lasting duration.

The establishment of a plant cover is another approach to a solution of this problem. Successful plant growth in problem areas is more permanent, is less expensive to attain and maintain, and lowers temperatures by shading. The plant cover reduces the morale problem by providing more comfort, lowering temperatures, and being esthetically pleasing.

Another approach to sand stabilization is the propagation of cuttings from native species. This was done in two ways. First, cuttings were made in the field and directly transferred to experimental sites. Second, cuttings of the same species were placed in a 10x12x10-foot propagation unit attached to a lath house, both of which were constructed for this project. Benches in the unit contain a lead-covered, thermostatically controlled, No. 19 heat cable ($10 w/ft^2$). The cable rests on 1 inch of coarse sand covered with 3 inches of Perlite (No. 2 grade). Watering of cuttings is through overhead 3/4-inch PVC piping equipped with mist nozzles. The timing (every 3 minutes) and duration of watering periods (5 to 6 seconds) are controlled by an automatic misting control unit (Lyon Electric No. A398). A rotary fan is used to circulate air in the unit, and the entire unit is covered with 75% Saran shade cloth.

Native Species

The following native species were used in this experiment:

Spinifex littoreus
Ipomoea pes-caprae
Ipomoea stolonifera
Vitex trifolia
Chrysopogon orientale

Many of these cuttings were treated with "Rootone," a proprietary root-stimulating chemical.

Care of Plants at Sites. All transplants were thoroughly watered immediately after placement in the ground and, until the advent of the rainy season, were watered from 4 to 6 times. The seeded areas were watered approximately 5 to 12 times during the same period. A noteworthy exception was the seeded area at Site 6 which was established late in August and was never given supplemental irrigation. Fertilizer, where applied, was done once at the time of planting.

There were some problems encountered in caring for the plants. The principal source of trouble was vehicle wheels, caused by drivers leaving the road for no apparent reason. Signs, stakes, and other barriers did not prevent this intrusion. Perhaps the only way to eliminate this problem would be to use prohibitively expensive fencing or armed guards. Drums of water placed by the side of the road to water transplants disappeared overnight as did stakes marking the plots. Foot traffic, bird consumption of seeds, lizards feeding on young plants, and soil-burrowing activity of various invertebrates also took their toll.

An essential feature of transplanting is to disturb the root system as little as possible. This is done by including a ball of soil on the roots of the plant to be moved; generally, a 1-foot-diameter ball of soil should be removed with a 1-to-2-foot shrub. While in transit, the ball of soil should be wrapped with wetted burlap or another water-absorbing material.

Replanting should occur as soon as possible after removal of the plant; this process can be hastened by digging holes of suitable size at the receiving site before moving the plant. The addition of a single fertilizer tablet (for example, Agriform 31-8-8) in each hole would increase the growth of the shrub. After transplanting, the soil around the plant should be compacted by foot and watered. Transplanting should, if possible, be done by those having some experience in the technique. Transplanting should be done in the rainy season to avoid drying the roots. Small shrubs, 1 to 2 feet in height, should be selected for transplanting.

Instead of completely removing plants, an alternative method is to cut 3- to 5-inch sections from the ends of branches of healthy plants and stimulate them to root. The cuttings should include several buds that are found in the angle made by the stem and leaf. A sharp knife should be used to prevent unnecessary damage to plant cells. Dipping the lower end of the cutting into a root-stimulating chemical, for example, Rootone, will increase the probability of rooting and decrease the time of rooting. After treatment, the lowermost leaves of the cutting should be removed to lessen water loss through transportation, and the bottom two inches of the cutting should be placed in a 4- to 5-inch bed of sand which is kept moist and shaded. The cuttings should be spaced approximately 1x1 inch. The propagation of cuttings requires a lath house or, at least, shaded trays of sand. The length of time between the preparation of the cuttings, their rooting, and their ultimate placement in the field is approximately 3 months. The time element should be considered if the cuttings are to be available when the secondary stabilizers, for example, grass, have become established. A late spring date is thus favored for collection of cuttings.

In general, the rooted plants transported from CONUS and Austrailia were not successful under the conditions of this experiment. The lack of success cannot be attributed to transportation difficulties, because delivery of the plants was performed most efficiently. This method was expensive, and none of the rooted plants were eminently successful. The plants were grown from seed gathered in the United States and other countries, notably Austrailia. The seeds could be imported into Vietnam and started in lath houses or comparable units. These units could be readily and inexpensively established throughout Cam Ranh.

Grass. Covering a small area with grass sod is the quickest technique for stabilizing the sand. Unfortunately, the Cam Ranh Peninsula does not have large amount of sod available, although the mainland east of Cam Ranh is a good source.

The sod should come from an environment as similar as possible to the area to be covered. For example, sod from a marsh land should not be used to cover hot barren sand in a dry region. Select a grassy spot that is level and cut the sod 2-inches deep into 12-inch-wide strips. Do not strip an entire area; leave 2-foot-wide strips of grass between areas where sod has been removed, thus allowing the remaining grass to spread horizontally and reestablish the grass cover. The sod should be put in place as soon as possible after collecting. The receiving area should be made ready before collecting the sod by raking to remove rubbish, wire, cement, etc. and then smoothing. The sod is placed on the sand and tamped with a homemade wood tamper or roller if a roller is available. A satisfactory roller can be made with an oil drum filled with water. Care should be taken to insure that the grass sod does not dry out and that watering follows the rolling process (Figure 12).

The process of seeding is similar to that used near the beaches though greater preparation can be made in cantonment areas. The soil should be raked, smoothed, and leveled. Fertilizer (20-20-15) should be spread at a rate of 5 lb N/1,000ft^2. Hand broadcasting from a 2-pound coffee can will serve as a satisfactory substitute for a fertilizer spreader. An even distribution of fertilizer is more important than an extremely accurate quantity.

Bermuda grass should be applied at the rate of 2 pounds of seed per 1,000 ft^2. A mechanical broadcaster is recommended, but again hand application from a 2-pound coffee can will serve as a satisfactory substitute. A little practice is required before the necessary even distribution of seed is attained.

After seeding, the sand should be lightly raked to cover the seed slightly. The sand should then be compacted. A lightweight roller is ideal, but a 24x24-inch piece of 3/4-inch plywood attached to a vertical handle will suffice. After compaction, the seed bed should be kept moist until the lawn is firmly established. If this watering schedule is impractical, seeding should be postponed until the rainy season has begun.

Fences. A basic preventive technique also consists of trapping the sand at the point of origin - the beach. This can be done to a great extent by the erection of mechanical barriers and by vegetation. Mechanical methods can be used two ways: (1) as a temporary stoppage or (2) as a means whereby the sand movement is stopped long enough for primary stabilizing plants to be established. A few of the mechanical barriers that are available are described here.

Brush fences consist of stakes sunk in the sand to a depth of 2 feet, placed 10 to 15 feet apart; brush is rammed into the ground between the stakes. This fence is readily constructed at the site, but in many parts of Cam Ranh there is not sufficient brush for this method. Certainly excessive amounts of brush should not be cut from one region to protect another.

Some of the variations of the brush fences are log barriers made of driftwood and logs, and brush barriers using shrubs inserted vertically in the sand or laid horizontally and held with wire. A combination of the readily available concertina wire and brush will provide a suitable barrier.

The arrangement of the fence is important. It should be located at approximately right angles to the direction of the major winds. Since the wind direction is not constant, a compromise may have to be made so that the fence varies in its angle to the wind. Where sand movement is particularly pronounced, the establishment of more than one fence row may be in order. Additional fences should be parallel and be approximately 15-feet apart. Parallel fences prevent the formation of sharply peaked dune crests which are more difficult to stabilize.

If the wind comes from many directions, a zigzag pattern or a diamond pattern can be used. These fences are placed parallel to the beach line. The number of fences used is directly proportional to the extent of sand movement.

Snow fences can be established any time after one has acquired knowledge of the intensity and direction of winds. A suggested time is at the end of the rainy season - generally it is too late to plant and is a suitable time to ascertain wind characteristics. Since approximately nine months will pass before planting occurs, the dunes will have attained a maturity that will aid in the establishment of stabilizing plants.

RECOMMENDATIONS

Prevent the occurrence of areas of unstable soil by leaving vegetation-covered areas undisturbed.

The decision to stabilize sand should include a complete long-range project to eliminate the problem.

Planning and scheduling are the most important ingredients for success in horticultural soil stabilization. All manpower, equipment, fertilizer, seeds, plants, and tools, down to the last rake, should be available at the sites.

Seeds should be of the most recent crop and should be well protected in storage. The storage time of seeds and transplants should be minimal.

Shipment of rooted cuttings from CONUS is not recommended because of poor survival rate.

Seeds should be imported from CONUS and Austrailia and germinated in Vietnam to provide more vigorous planting stock.

Mechanical barriers, such as snow fences, should be used to temporarily stop sand movement so that plant stabilization projects will be more successful.

Fertilizer having a high nitrogen-to-phosphorus ratio should be used in a readily soluble form.

For primary soil stabilization plant Ammophila arenaria, a CONUS import, and Spinifex littoreus, a native plant.

For secondary soil stabilization plant Bermuda grass, Zoysia, Canavalia, Vitex trifolia, and species of Ipomoea.

For tertiary soil stabilization plant Vitex trifolia, Casuarina equisetifolia, Euphorbia atoto, Vatica tonkinensis, and Albizzia nigricans. These plants represent the climax or stable plant community.

REFERENCES

NCEL VLAP Special Report, NRDU-V61-69 of April 1971.

Appendix E

INTERENVIRONMENTAL FAST-CURING CONCRETE

I. The need exists for off-the-shelf, durable, versatile, fast-curing concrete mix products that provide a concrete suitable for repair work and new construction. Economical, non-proprietary materials, that function in both on-shore and marine environments at various temperatures are required.

II. Recommended materials for mix designs are as follows:

A. Use normal fine and coarse aggregates.

B. Add normal amounts of ASTM Type III (High Early Strength) Portland Cement.

C. Add Calcium Chloride.

1. 4% of cement weight for low-slump.

2. 6% of cement weight for high-slump.

D. Use seawater or potable water.

III. Table I provides a summary of pertinent test results, extracted from Naval Civil Engineering letter report of August 1971, entitled: "Fast Setting Cementitious Materials for Repairing Naval Concrete Structures".

A. Additional pertinent characteristics of Calcium Chloride are as follows:

1. Calcium Chloride has an unlimited shelf life while stored in airtight containers and in unventilated compartments (similar storage as for cement).

2. Not hazardous during shipment, storage, or application.

3. Mix, product may be applied on shore and underwater.

4. Cost of Calcium Chloride per cubic yard of concrete, when considering 6% ratio to cement, by weight, is approximately $3.33 (considered inexpensive).

5. Calcium Chloride accelerates curing time, thus allowing the new or repaired facilities to be used rapidly (see Table I).

6. It is a generic, non-proprietary, readily available, off-the-shelf material.

7. Caution: Use of Calcium Chloride will result in slight corrosion of reinforcing bar. However, this is not considered critical for duration of an advanced base (approximately 5 years).

IV. Potential uses of rapid-curing concrete are as follows:

A. Repair of damaged or deteriorated runways, taxiways, bridge piers, piles, roads, helo-pads, bunkers, sewers, wharves, dams, buildings, and other structural elements compatible with concrete.

B. New work where fast-curing concrete will expedite the project, including underwater applications.

Table 1

Compressive Strength (PSI)				AT Curing Age of			
1 Hour	4 Hours	24 Hours	7 Days	1 Hour	4 Hours	24 Hours	7 Days
Low Slump Concrete = 3"-3-1/2				High Slump Concrete = 7-7-1/4"			
Air Cured at 33° F and 50% Relative Humidity							
0	30	870	3680	25	28	572	2260
Cured and Tested in 33° F Seawater at 27 PSI Pressure; slump = 7-1/4"							
—	—	—	—	340	417	850	
Air Cured at 63° F and 50% RH							
30	630	1550	1740	21	440	2200	2740
Cured and Tested in 63° F Seawater at 27 PSI Pressure; slump = 7"							
—	—	—	—	62	225	2330	—
Air Cured at 93° F and 50% RH							
41	960	2500	2780	27	707	1960	2650
Cured and Tested in 93°F Seawater at 27 PSI Pressure; slump = 7"							
—	—	—	—	229	799	3400	—

NOTES:

1. Table 1 summarizes test results of fast-curing interenvironmental concrete mix, using seawater; high early strength (ASTM Type III) Portland Cement; Calcium Chloride accelerator - 4% for low-slump, 6% for high-slump mix based on cement weight.
2. Potable water may be used in lieu of seawater.
3. Setting times, based on 6% Calcium Chloride to cement weight, W/C ratio of 0.36 by weight, ambient temperature of 73° F and RH of 59%, are:

   a. Initial set - 23 minutes.

   b. Final set - 47 minutes.