PA29,222 AD 649 375

CHEMICAL STABILIZATION OF BEACH SAND

C.V. Brouillette

U.S. Naval Civil Engineering Research and Evaluation Laboratory
Port Hueneme, California

September 1956

NOTICE TO DEFENSE DOCUMENTATION CENTER USERS

This document is being distributed by the Clearinghouse for Federal Scientific and Technical Information, Department of Commerce, as a result of a recent agreement between the Department of Defense (DOD) and the Department of Commerce (DOC).

The Clearinghouse is distributing unclassified, unlimited documents which are or have been announced in the Technical Abstract Bulletin (TAB) of the Defense Documentation Center.

The price does not apply for registered users of the DDC services.

Project NY 440 008.1
Technical Memorandum M-096

CHEMICAL STABILIZATION OF BEACH SAND

1 December 1954 (revised September 1956)

u. s.
naval
civil
engineering
research
and
evaluation
laboratory

port hueneme,
california

U.S. Naval Civil Engineering Research and Evaluation Laboratory
Port Hueneme, California

Project NY 440 008.1
Technical Memorandum M-096

CHEMICAL STABILIZATION OF BEACH SAND

PART I X-72 DIAMINE MODIFICATION OF THE ANILINE-FURFURAL METHOD OF BEACH SAND STABILIZATION

PART II OPERATIONAL PROCEDURE FOR PREPARATION OF STABILIZED BEACH SAND ROADWAY

1 December 1954 (revised September 1956)

C. V. Brouillette

SUMMARY

A process has been developed for introducing resin-forming chemicals into sand on a beach for the purpose of producing a hard-surfaced road for use by military vehicles during an amphibious landing.

The chemical formulation X-72 was the result of several years of chemical research by the U.S. Naval Civil Engineering Research and Evaluation Laboratory. With the cooperation of units of the U.S. Marine Corps at Camp Pendleton, Oceanside, California,

during three amphibious landing exercises wherein roadways were stabilized in the beach sand and subjected to heavy military traffic loading by the Marines, the diamine modification of the aniline-furfural method of beach sand stabilization was proven to be feasible.

This memorandum of procedure for chemical beach sand stabilization was prepared for use by amphibious personnel. Included are required qualifications for the personnel and suggested safety precautions.

CONTENTS

ILLUSTRATIONS

CHEMICAL STABILIZATION OF BEACH SAND

To acquaint amphibious personnel with the diamine modification of the aniline-furfural method for chemically stabilizing beach sand.

PART I X-72 DIAMINE MODIFICATION OF THE ANILINE-FURFURAL METHOD OF BEACH SAND STABILIZATION

INTRODUCTION

Objective

The needs of an amphibious attack force on a hostile beach are usually supplied, during the initial stages of an attack, by amphibious craft. All supplies and equipment must be transported from the water's edge at the ramp of a landing boat or from the end of a causeway, over the beach sand extending to the supply (rendezvous) area. To expedite logistics during this phase, a method was sought by which a hard-surfaced roadway of chemically stabilized sand could be processed that would support all vehicular traffic (with the exception of vehicles using cleated tread) twenty minutes after being processed.

Historical Background

Aniline and furfural catalyzed by a suitable acid were first employed to stabilize beach sand by Dr. Hans Winterkorn of Princeton University. Previous research by Dr. Winterkorn was directed toward improvement of roadways constructed of bitumen incorporated with aggregate or soil. He discovered that furfural alone or mixed with other chemicals improved the wetting power of the bi-

tumen for mineral aggregate used for constructing bituminous load-bearing surfaces. He obtained a patent, U.S. 2314181, 16 March 1943, covering this improvement in bituminous roadways and a royalty free license for its use was granted to the Government of the United States.

However, during World War II the need for a quick setting chemical formulation to bind or stabilize beach sand into a serviceable roadway was demonstrated. In 1948, Dr. Winterkorn received a contract with the Navy to develop such a formulation.

In 1950, the U.S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, California became actively involved in this project. At this stage of development, the formulations consisted of mixtures of pitch, aniline, furfural, acid salts, and various relatively insoluble catalysts. When these formulations were processed with beach sand the resulting roadway required a curing or setting time of approximately 8 hours before heavy wheeled vehicles could traverse or stand safely on the roadway.

Dr. H. McKennis, Jr., Dr. W. M. Foley, Jr., and Mr. C. V. Brouillette of the Chemistry Division of NAVCERELAB initiated a program of research into the chemistry of the catalyzed aniline-furfural reactions and demonstrated that by controlled polymerization of the products and by novel modifications (incorporating polyfunctional amines and acids) of the formulation, a short hardening period and a very strong, serviceable roadway would be achieved.

Initial formulations had contained dry material which needed to be spread across the beach sand ahead of the stabilization equipment. Other chemicals were more or less in suspension in the liquid portions of the formulation. Heat was required (over 150 F) to maintain a completely fluid mix during the stabilization operations. Participation in full scale landing exercises at Camp Pendleton, California, demonstrated the need for a completely liquid mix, free of suspended chemicals, with such desirable features as increased polymerization, faster set, greater effectiveness in wet sand and better wetting properties.

This Laboratory discovered that the use of m-phenylenediamine and citric acid produced the desired quick set and gave additional strength to the finished roadway. Alcohol was added to maintain

solution of the chemicals and to insure complete reaction of the chemicals during the final period of the resinification. A wetting agent was used to insure complete binding between the resinous chemical binder and the wet or dry sand, as the case may be.

The resulting Formulation X-72 consisted of two components, an aniline solution and a furfural solution, which could be mixed into beach sand to produce a roadway capable of supporting military traffic twenty minutes after being processed.

By actual count, 643 rubber-tired military vehicles, having a total weight of 5,500,000 lb, passed over a chemically stabilized beach sand roadway in twenty-six hours during amphibious landing exercises at Camp Pendleton, California. Small sections of the roadway were disintegrated during these traffic loadings. This severe damage to the roadway was attributed either to poor compaction of the chemical sand mix or to loosened or soft supporting sand. Except for these mechanical failures, the useful life of the roadway would be several months.

METHOD

The subject formulation, X-72, appeared superior to others evolved from the work of the Laboratory. The process and techniques for chemically stabilizing beach sand by use of Formulation X-72 were developed with the assistance of units of the U. S. Marine Corps at Camp Pendleton, Oceanside, California, during the staging of several amphibious landing exercises (see Figure 1).

This process depends upon rapid polymerization of chemicals into a resinous binder. The chemicals used in Formulation X-72 are: aniline, furfural, and meta-phenylenediamine, with citric acid used for a catalyst.

The stabilizing chemicals are prepared as two separate solutions: the aniline solution (Solution A), and the furfural solution (Solution F). Denatured alcohol is employed in Solution A to aid in the dissolution of the citric acid and to act as a solvent for Solution A and Solution F during the latter stages of their reaction. A non-ionic wetting agent is employed in Solution F to assist the resinous binder in wetting the beach sand. The weight of resinous binder is calculated at 6 per cent of the weight of the beach sand incorporated into the roadway.

Figure 1. Beach sand stabilization equipment in amphibious landing exercise.

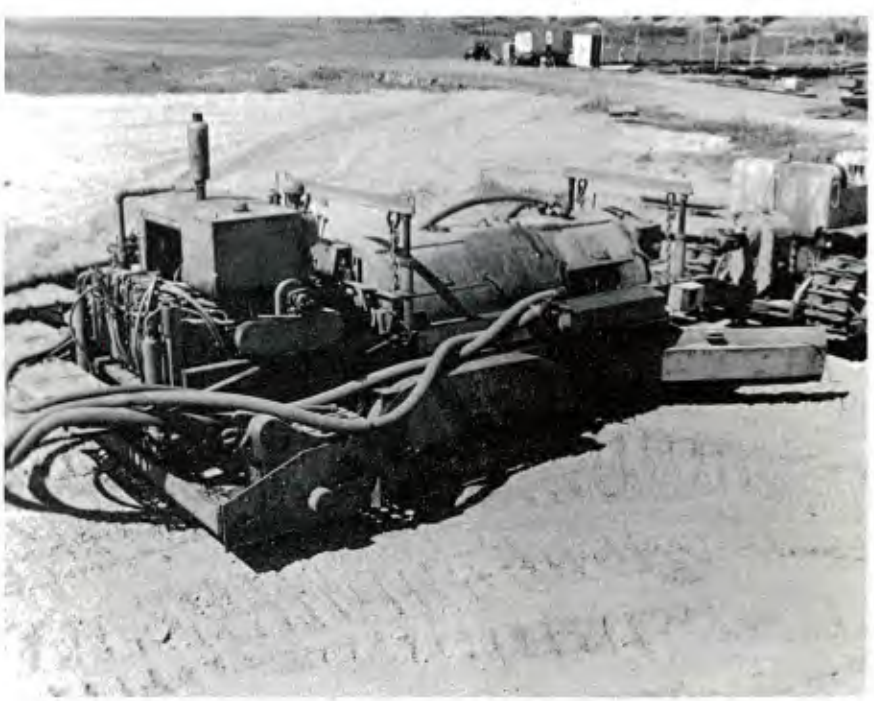

Figure 2. Wood Roadmixer.

The processing equipment consists of a Wood Roadmixer (Figure 2), an Athey rig (Figure 3), and two tractors. The Wood Roadmixer consists primarily of a set of forward wings or blades (Figure 4), a pug mill (Figure 5), a helical spreader (Figure 6), and a vibratory-compaction mechanism (Figure 7).

The forward wings gather sand at a pre-set width of 12 ft and depth of 6 in. The pug mill receives the sand and mixes it with the chemicals which are being introduced by two nozzles placed at the forward end of the pug mill. The pug mill deposits the sand chemical mix at its after end in the form of a windrow. At this stage the mix is very soft and loose. The helical spreader evenly distributes the windrow so that it neatly fills the 12-ft-wide, 6 in.-deep area created by the wings. The vibratory-compaction mechanism screeds the chemical sand mixture and applies pressure accompanied by heavy vibratory action to compact this mixture into a firm roadway (see Figure 7).

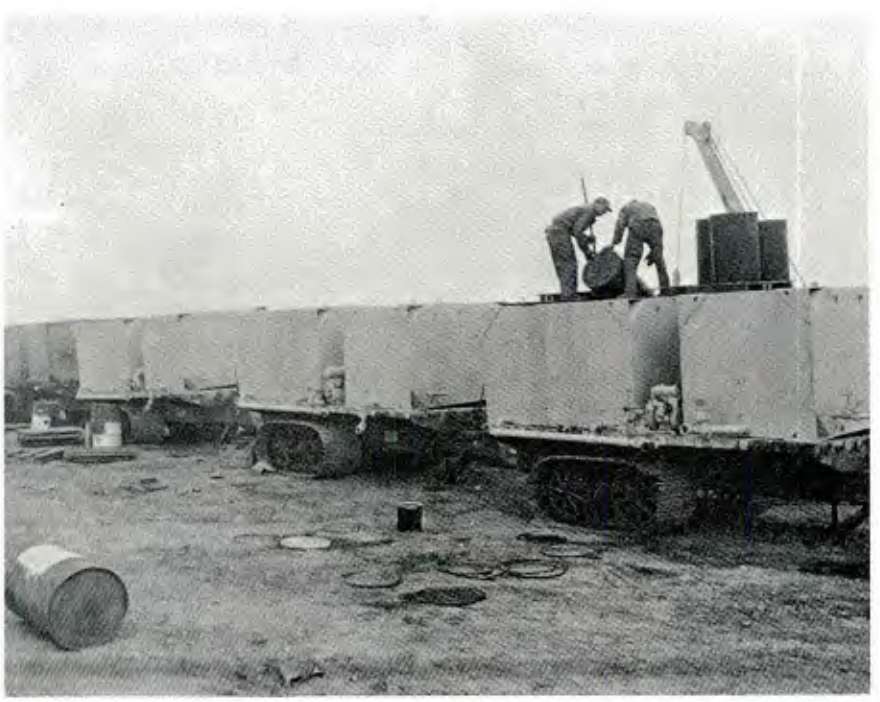

Figure 3. Chemical tanks (Athey rig).

Figure 4. Sand gathering wings.

Figure 5. Pug mill with two spray nozzles.

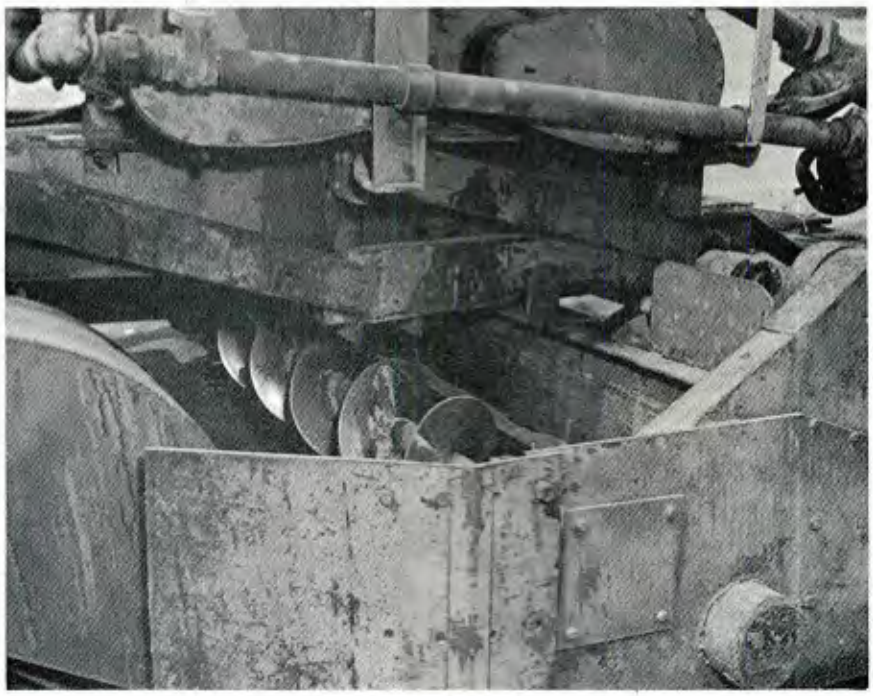

Figure 6. Helical spreaders and control.

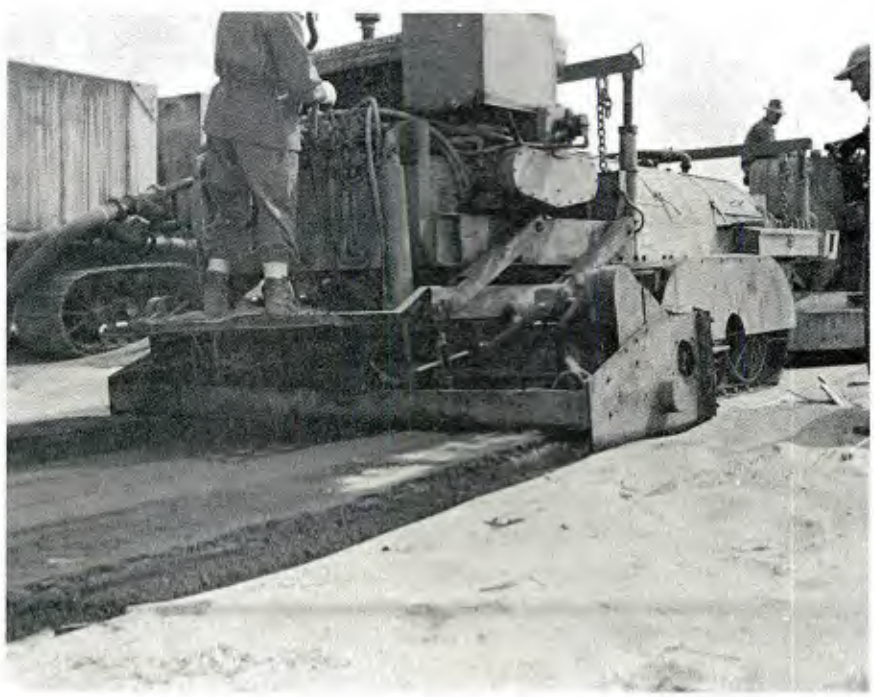

Figure 7. Pressure loading and control of hydraulic vibratory compaction mechanism.

REQUIREMENTS

Chemicals

The following table lists the chemicals needed to stabilize one continuous strip of beach sand, 600 ft long, 12 ft wide, and 6 in. thick; and the quantity, cost, and packaging of these chemicals. These are the maximum quantities which should be used in the equipment described.

TABLE I. Quantities and cost of chemical in diamine modification of Formulation X-72.

Solution A				
Chemical	Quantity	Wt (lb)	Cost (1954)	Packaging
Aniline Oil	22 drums	9900	$1980.00	55-gal metal drum
*m-phenylenediamine	8 drums	2200	$1980.00	275-lb fiber drum
Anhydrous citric acid	8 drums	2000	$ 570.00	250-lb fiber drum
Denatured alcohol	340 gal	2200	$ 255.00	50-gal metal drum

Solution F				
Chemical	Quantity	Wt (lb)	Cost (1954)	Packaging
Furfural	13 drums	6185	$ 865.00	55-gal metal drum
Wetting agent (non-ionic)	5 gal	40	$ 18.50	5-gal metal can

*CAUTION: m-phenylenediamine MUST NOT be procured from the manufacturer until such time as it can be dissolved in aniline upon arrival. The "life" of m-phenylenediamine after manufacture is 2 to 3 months. At the end of 5 to 6 months or sooner a tar like residue will in all probability result. After being mixed into Solution A, the life of the m-phenylenediamine is estimated to be approximately 24 months.

Solution A totaled 1890 gal, weighed 16,300 lb, and was packaged in thirty-eight 55-gal drums. Its cost (1954) was approximately $4785.00.

Solution F totaled 695 gal, weighed 6225 lb, and was packaged in thirteen 55-gal drums. Its cost (1954) was approximately $883.50.

The completed Formulation X-72 (combination of Solutions A and F) totaled 2585 gal, weighed 22,525 lb, and was packaged in fifty-one 55-gal drums. Total cost (1954) for the formulation to process a strip of the dimensions listed was approximately $5668.50.

These solutions should be prepared commercially and supplied in steel drums, if at all possible, rather than prepared and mixed by members of the stabilization team.

Some possible sources of these chemicals are listed in Appendix I.

Equipment

(NOTE: The photographs illustrating equipment were taken during the experimental stages of development, when the chemical tanks and Roadmixer were operated side-by-side. The preferred and recommended procedure, however, is for tandem operation, with the chemical tanks preceding the Roadmixer. Thus, the descriptions of the equipment include necessary requirements and changes needed for tandem operation, but the photographs are of the experimental or side-by-side procedures.)

WOOD ROADMIXER. The Wood Roadmixer, Model 54-N (1953), (see Figures 1 and 2), modified as specified in Appendix II, is the machine used to mix the sand and chemicals and to smooth and compact the mix into a firm roadway. It is manufactured by Pettibone-Wood Manufacturing Company, 6900 Tujunga Avenue, North Hollywood, California

Auxiliary Transmission. An auxiliary transmission manufactured by the Pettibone-Wood Manufacturing Company is used to transfer power from the towing tractor to the Roadmixer.

In order to get the correct auxiliary transmission it is necessary to specify the exact heavy-duty tractor that will be used for

towing the Roadmixer. Each make of tractor requires its own specific power take-off.

TRACTORS. Two tractors are needed for the stabilization operation: one for pulling and powering the Wood Roadmixer and one for towing the chemical tank rig.

Tractor for Towing Chemical Tanks. The tractor for towing the chemical tank rig can be one of the following or one similar:

1. D-7, manufactured by Caterpillar Tractor Company, Peoria, Illinois.

2. HD-10, manufactured by Allis-Chalmers Manufacturing Company, Tractor Division, Milwaukee, Wisconsin.

3. TD-18A, manufactured by International Harvester Company, 180 N. Michigan Avenue, Chicago, Illinois.

Tractor for Towing and Supplying Power to Roadmixer. The tractor for towing the Wood Roadmixer and supplying power to its pug mill can be one of the following or one similar:

1. D-8, manufactured by Caterpillar Tractor Company, Peoria, Illinois.

2. HD-19, manufactured by Allis-Chalmers Manufacturing Company, Tractor Division, Milwaukee, Wisconsin.

3. TD-24, manufactured by International Harvester Company, 180 N. Michigan Avenue, Chicago, Illinois.

This tractor should have brackets welded to the left side of the frame to support two pipes of the proper size to connect with 3-in. ID rubber hoses running between the vehicles. These pipes are connected at the forward end with the hoses which supply Solutions A and F from the chemical tanks on the Athey wagon. At the rear end they are connected to additional lengths of rubber hose to supply the two solutions to the Wood Roadmixer pug mill. Quick-disconnect hose-to-pipe couplings are used for these connections.

This arrangement permits tandem operation of the Roadmixer and chemical tanks by providing a rigid bridge between the lengths of hose. The stabilization equipment can thus traverse the most level and unobstructed route during the stabilization run and can more easily detour around any depression or obstruction on the beach.

CHEMICAL TANKS (ATHEY RIG) (see Figure 3). The chemical tanks for transporting and supplying Solutions A and F can be constructed from Mark T-6B pontoons and mounted on a 15-ton Athey wagon. Any two-compartment tank whose capacity is 800 gal in one compartment and 2200 gal in the other, and that is fitted with steam heating coils and is mounted on a full track, can be used.

Tank F. Tank F consists of one Mark T-6B pontoon fitted by welding with a 2-in. iron pipe which is used for steam heating the chemical solution. This iron pipe enters the tank at one end, approximately 18 inches from the bottom of the tank, makes an S-shape across the inside, and comes out at the opposite end of the tank. The tank is fitted with an effluent 3-in.-pipe manifold connected by an elbow into the bottom corner of one side of the tank and by a T-connection at the other corner of the same side (see Figure 8). If the left side is used, it will facilitate connection with the pipes welded to the tractor.

Tank A. Tank A consists of two Mark T-6B pontoons with one side cut out of each and the two pontoons welded together to make one large tank. It is fitted for steam heating pipes and effluent manifold in the same manner as Tank F described above.

Athey Wagon. The Athey wagon is the military-type, full-track, 15-ton capacity trailer.

The two tanks are mounted on the Athey wagon in such a way that the steam heating pipe from the furfural tank is connected directly to the steam heating pipe of the aniline tank. The tanks are further arranged so that the side opposite the effluent manifold is elevated approximately 8 inches in order to more easily drain the chemicals through the manifold (see Figure 9).

Figure 8. Connecting pump lines to chemical tank.

Figure 9. Stabilizing beach sand with chemical mix (note elevation of one side of chemical tank to permit easy draining).

STEAM GENERATOR (see Figure 10). A steam generator is necessary for supplying steam for the heating coils of the chemical tanks. The following heater was used satisfactorily:

> Tank Car Heater, Model DS-3 (3-car model), manufactured by Cleaver-Brooks Company, Milwaukee, Wisconsin.

HAMMER MILL. The m-phenylenediamine can be ground to a fine crystal by means of a hammer mill. The following machine was used satisfactorily:

> Hammer King Mill, M-118-395, Continental 6-Cylinder Gasoline Engine Driven, manufactured by David Bradley Manufacturing Works, Bradley, Illinois.

KOEHRING CRANE (see Figure 11). This equipment is used for loading and hoisting chemicals:

> Koehring Crane, Model 205-2M (Marine Shore Party Crane), manufactured by Koehring Company, 3038 W. Concordia Avenue, Milwaukee 16, Wisconsin.

SAFETY GEAR. All safety gear required is standard Navy issue, except the gas mask.

Gas Mask. Each member of the stabilization team must have a gas mask (see Figure 12). The mask used satisfactorily during tests was the M-S-A All-Service Gas Mask, Model S, with All-Service Canister, 1952, Cat. No. Ea-40654, Model 5, manufactured by the Mine Safety Appliance Company, Pittsburgh, Pennsylvania. (This mask cannot be worn comfortably over glasses; therefore it is suggested that this be considered when qualifying men. Masks with specially fitted prescription lenses in the eyepieces could be used.) A Navy issue gas mask using the All-Service Canister would be satisfactory.

Respirator. Personnel grinding diamine should wear standard Navy-issue dustproof respirator.

Leather Gloves. Heavy-duty leather gloves are best for protecting the hands when handling and mixing chemicals.

Figure 10. Steam generator.

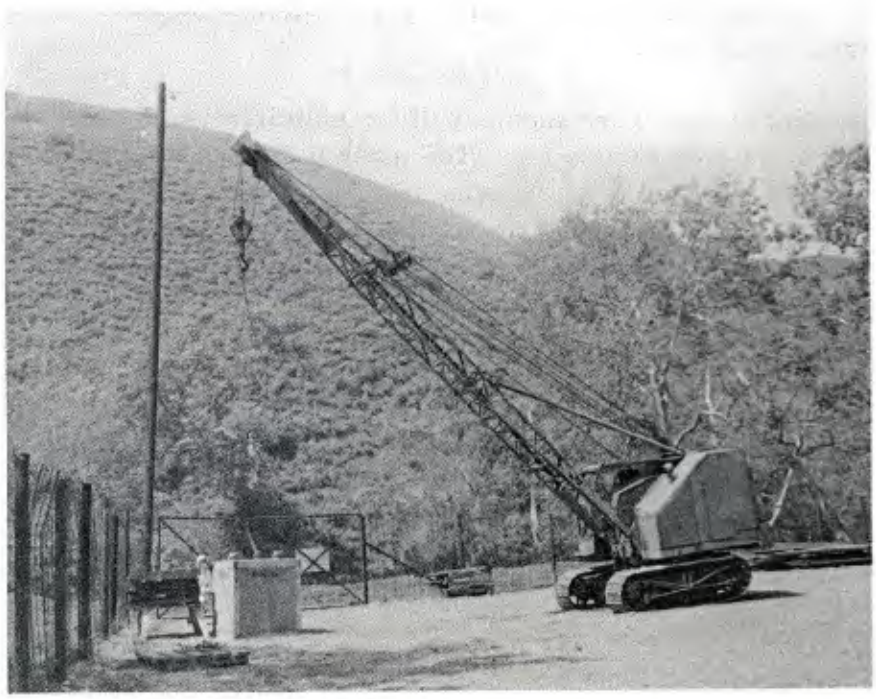

Figure 11. Koehring crane.

Figure 12. Stabilizing personnel wearing gas masks.

Foul-Weather Coat and Trousers. Amphibious-type foul-weather coat (with hood) and trousers are recommended for use when grinding "diamine."

Decontaminating Solution. Decontaminating solutions of soap and water should be immediately available in case of accidental wetting of clothing or body of stabilizing team personnel by either Solution A or Solution F.

Personnel

The beach sand stabilization team consists of a minimum of five men. The dissolution and preparation of chemicals require an additional two men if the chemical solutions are not prepared commercially.

STABILIZATION TEAM LEADER. A petty officer in the rate of Driver First Class (CD1) or higher is in charge of the stabilization team. He is directly responsible to the Beach Party Commander or other officer delegated with authority over the team.

Prior to the stabilization run he reconnoiters the beach to be sure of the specific route for the stabilization run. He makes every effort to level any humps and to remove any obstacles still remaining in the path of the run or chooses the best route to detour around them.

During the stabilization run he rides aboard the Wood Roadmixer and adjusts the chemical-control valves (see Figure 13). He assists the Utility Man with the control of the chemical pumps when under way.

Figure 13. Close-up of chemical pumps, meters, and control valves.

He supervises preparation of the chemical solutions during emergency conditions (if they are not prepared commercially).

He has a general knowledge of first aid and of the toxicity and inflammability of the chemicals. He is familiar with dozer, crane, and steam-generator problems and operations, and with the operation of all phases of the Wood Roadmixer.

DRIVERS. Two men in the rate of Driver (CD) are qualified to drive the two tractors used in towing and operating the stabilizing equipment during the run. These men are familiar with the toxicity of the chemicals and with first-aid measures in case of contamination.

MECHANIC. One man in the rate of Mechanic Third Class (CM3) or higher is responsible for the efficient mechanical operation of the Wood Roadmixer. During the stabilization run he operates the helical spreaders and the vibratory-compaction mechanism. He is familiar with the procedure for calibration of the chemical pumps to insure delivery of the required quantity of chemicals during a stabilization run. He is familiar with the toxicity of the chemicals and with first-aid measures in case of contamination.

UTILITIES MAN. One man in the rate of Utilities Man (UT) is qualified to assist the Mechanic with general maintenance of the Wood Roadmixer. This man is familiar with piping, valves, and metering devices for liquids. During the stabilization run he operates the chemical pumps and the sand-gathering wings on the Roadmixer. (The petty officer in charge of the stabilization team assists him with control of the chemical pumps when under way.) He is familiar with the toxicity of the chemicals and with first-aid measures in case of contamination.

ADDITIONAL MEN FOR PREPARATION OF CHEMICALS. If the chemical solutions can not be prepared commercially, an additional two men in the rate of Utilities Man (UT) are needed who are qualified to grind "diamine" prior to preparation of Solution A (aniline solution). These men are not considered part of the stabilization team. If required, however, they will assist with the preparation of the chemical solutions. They are familiar with the toxicity of the chemicals and with first-aid measures in case of contamination.

LIMITATIONS

Sand

The beach sand is a major strength-determining factor in the chemically stabilized beach sand roadway.

TYPE. If the beach sand is mostly silica and/or silicates, the roadway will become hard and serviceable; if the beach sand is mostly coral or carbonates, the roadway will become easily scuffed and crumpled.

No experimentation with volcanic ash or extreme gradation of sand was conducted during development of Forumulation X-72. Since the formulation does not use water as a solvent, it functions satisfactorily over wide ranges of salinity and calcareous alkalinity. However, alkalinity attributed to ammonia or strong alkali would prevent resinification of the chemicals.

PHYSICAL CONDITION. The beach must be cleaned of debris and have all contours leveled. Barbed wire, boards, or large rocks will overload the helical spreader of the Wood Roadmixer and also disrupt the screeding process of the vibratory-compaction mechanism. The sand surface should contain no loosened or filled areas.

TEMPERATURE. Beach sand temperatures below about 45 F retard evaporation of the volatile material present during the chemical reaction between Solution A and Solution F in the beach sand. The beach sand stabilized under these conditions takes a much longer time to become hard enough to support heavy traffic. Thus it is advisable to heat Solutions A and F by use of the steam heating lines to temperatures of about 100 F for sand temperatures around 45 F, and to about 125 F for sand temperatures around 32 F.

MOISTURE. The diamine modification of the aniline-furfural method has been used to stabilize beach sand during conditions of mild precipitation. However, most satisfactory results can be expected from sand conditions encountered during clear weather.

Chemicals

TOXICITY. The chemicals used in the diamine modification of the aniline-furfural method of beach sand stabilization are toxic, and extreme caution must be exercised in their use. Detailed statements about the toxicity of each chemical, precautions to take in their use, and first-aid measures in case of accidental exposure are included in Appendix III. The toxic hazard encountered in working with these chemicals can be greatly reduced by the use of proper safety gear and precautions.

COST. For quantities of chemicals required and the breakdown of their cost see REQUIREMENTS, Chemicals, page 8.

STORAGE LIFE. Solution F can be stored for long periods of time without deterioration. Solution A deteriorates with time. After 24 months' storage, its use in the Formulation X-72 results in a slower setting roadway. However, the resulting roadway after being allowed to set for 24 hours will have greater strength than a roadway made with fresh solutions.

To reduce the setting time of the roadway again to approximately 20 minutes, it is necessary to incorporate additional citric acid into the chemical sand mixture at the time the roadway is being processed. The citric acid should be distributed uniformly, by hand or machine, in a windrow down the center of the proposed roadway. Six hundred pounds of citric acid are required when the full load of Solutions A and F are used. This amounts to one pound per linear foot of roadway.

During preparation of solution A, heat is required to dissolve the citric acid. Storage of Solution A at a temperature of 36 F does not, however, cause the citric acid to crystallize out.

Equipment

The forward rate of the stabilization equipment is 17 ft per minute. It has a turning radius of about 50 feet. The length of the Wood Roadmixer is such that it cannot efficiently process the roadway when passing over contours in the sand; therefore, these must be eliminated or avoided.

Roadway

The diamine modified aniline-furfural processed roadway requires about 20 minutes to become hard enough to support wheeled traffic.

If properly compacted and not misused, the roadway should have a useful life of up to several months; however, mechanical failures because of poor compaction or loosened or soft supporting sand may shorten this period.

Misuse will cause premature failing. Cleated treads will cut into the roadway and cause it to fail. The edges will fail rapidly if equipment operates off and on the roadway at the edges. It is highly recommended that a shoulder of sand be scooped onto both edges along the full length of the roadway. This shoulder will distribute the weight from any traffic loading at the edges and minimize crumbling.

ALTERNATIVE METHOD (S-1 FORMULATION)

During the chemical research a second formulation, designated S-1, was developed which would stabilize beach sand but was not as easily processed into the sand as Formulation X-72. The catalyst used in Formulation S-1 is a dry component not soluble in Solution A or Solution F and therefore would necessitate processing three components, whereas X-72 requires only two components to be processed. A dry-spreader would be required to distribute the dry component onto the beach sand ahead of the Wood Roadmixer. Beach sand stabilization using this method would thus require equipment not yet developed; therefore, it has not been tested operationally. Formulation S-1 is included in Appendix IV for purposes of comparison.

PART II OPERATIONAL PROCEDURE FOR PREPARATION OF STABILIZED BEACH SAND ROADWAY

PROCEDURE BEFORE OPERATION

Familiarization With Equipment

If possible, have the stabilization team checked out on the operation of the Wood Roadmixer by a factory representative. Personnel must become familiar with and be able to operate the component equipment as follows:

PUG MILL AND SAND-GATHERING WINGS (see Figures 4 and 5). Great skill must be acquired to control the depth of cut in the beach sand to the required six inches. As the Roadmixer tends to pitch or rock on its horizontal axis, the wings cut varying depths into the sand unless carefully controlled by skillful operation of the raising and lowering controls. The pug mill rises and lowers simultaneously with the gathering wings.

CHEMICAL PUMPS AND METERS (see Figure 13). These pumps are calibrated and preset by the operator to deliver the required quantities of Solution A and Solution F.

HELICAL SPREADERS (see Figure 6). Great skill must also be acquired in operating the helical spreaders. The operator must distribute the chemical sand mix which has been deposited as a windrow at the rear of the pug mill. The distribution must be regulated so as to completely and evenly fill the 12-ft-wide, 6-in.-deep void created by the gathering wings when gathering sand. The helical spreaders have reversing controls to control spreading to either left or right.

On a turn, more of the windrow passes under the vibratory compactor at the inside of the turn. Skill should be acquired, therefore, in feeding more mix to the outside portion of the turn.

If more of the windrow passes under one side of the vibratory compactor than the other, it will lift this side and cause the opposite side to undercompact. The undercompaction will result in early failure of the roadway. Some compensation can be obtained by additional pressure loading of the side containing less mix.

VIBRATORY-COMPACTION MECHANISM (see Figure 7). This mechanism has two primary functions: first, it screeds the chemical sand mix after it has been spread by the helical spreaders; and second, it compacts the chemical sand mix into a firm roadway. The mix produced by the pug mill is very loose, soft, and highly aerated. If allowed to harden in this condition the resulting product is very easily crumbled.

Repeated trials should be made, preferably using the actual chemicals (Formulation X-72), in order to set the vibratory-compaction mechanism at the proper angle to the horizontal plane for correct screeding. This is usually with the forward edge slightly higher than the rear edge. When correct screeding is obtained the mix passes smoothly beneath the vibratory compactor without sticking to its baseplate. A smooth, hard, well-compacted roadway will result. Usually it is advisable to over-correct and undercorrect the angle of attack of the front edge of the compactor to determine the proper setting.

Pressure loading of the vibratory-compaction mechanism must be uniform. Too much loading on one end of the mechanism will cause the opposite end to undercompact. This results in a weak, friable roadway. The vibratory compactor does not function well on turns. The compaction of the chemical sand mix is less at the outside portion of the turn. Additional pressure loading should be attempted on the side of the vibratory compactor making the outside part of the turn.

SPRAY NOZZLES. The two spray nozzles for chemicals are mounted as far forward as is practicable on the pug mill of the Wood Roadmixer. They are positioned side by side (see Figure 5) at the top of the pug mill, and set in such a way that the two solutions, A and F, will blend together while being sprayed.

HORN. A horn on the Roadmixer is used by the stabilization team leader to signal starting and stopping. The signals should be thoroughly understood by both tractor drivers and the Roadmixer operators.

Trial Exercises

Teamwork and skill in beach sand stabilization can be acquired only through practice. Water can be used in the chemical tanks during practice procedures until the crew is familiar with and proficient at the stabilization process.

Conduct these trial exercises as follows:

1. Partly fill chemical tanks A and F with water. They can be loaded by placing the suction line from a pump on the Roadmixer into the water and placing the delivery line from the pump into the top of the chemical tank. When using chemicals, this is a much simpler loading procedure than hoisting the drums and pouring the solutions into the tanks by hand.

2. Stake out measured intervals of 10 ft each along a level strip of beach (see Figure 14). These are for use in gauging the rate of flow of the chemicals.

3. Adjust metering system to deliver the required number of gallons through the spray nozzle in the pug mill while the Roadmixer is being operated past the stakes. This is 30 gal per 10 ft for the aniline solution (Tank A), and 11 gal per 10 ft for the furfural solution (Tank F). Slight adjustments may be necessary in metering when using the chemical solutions.

4. Operate Wood Roadmixer along a proposed roadway site at the normal rate of travel of 17 ft per minute. The tractor towing the Roadmixer, which is the mixing unit of the stabilization equipment, sets the pace. This rate of travel was selected to obtain a retention time in the pug mill sufficient for efficient mixing of sand and chemicals. The pug mill rotor rpm and the forward travel rate of the equipment are controlled by the gear train of the auxiliary transmission furnished with the Roadmixer. Tractor drivers should be able to pace each other at approximately 17 ft per minute.

Figure 14. Beach staked out at 10-foot intervals.

Figure 15. Team and equipment stabilizing beach sand.

5. Adjust the forward speed of the tractor towing the chemical tanks and preceding the tractor towing the Wood Roadmixer so that the rubber hoses running from the Athey rig do not become entangled.

6. Take care to avoid traveling over uneven terrain or through loosened or uncompacted sand. This can cause the pug mill to become overloaded by allowing the gathering wings to scoop in excessive amounts of sand. Also avoid traveling up too steep a grade or through loose sand where the towing tractor can become stalled or bogged down.

After becoming proficient with trial runs using water, perform trial exercises using the chemical mix for actually stabilizing beach sand (see Figures 9 and 15).

CAUTION: Gas masks, protective clothing, and heavy leather gloves must be worn when operating with chemicals.

Preparation of Chemicals

The solutions should be prepared commercially and supplied in steel drums, since preparation of Solution A without commercial equipment is extremely hazardous. The beach sand stabilization team should be responsible only for the actual processing of the stabilized roadway. However, under emergency conditions the following method of preparing the solutions can be used (see Appendix III for hazardous properties of chemicals):

SOLUTION A. Mixing the chemicals for preparation of Solution A (aniline) sufficient for stabilizing 600 feet of roadway can be performed in the large aniline tank aboard the Athey wagon if necessary. If one is available, use a special mixing tank as described in Appendix V instead of the pontoon tank for mixing.

CAUTION: Good ventilation is required. No smoking or open flames should be permitted around the heated solutions.

1. Have the following chemicals ready at the mixing site:

   a. Aniline oil, 22 drums (9900 lb).
   b. m-phenylenediamine (referred to as "diamine"), 8 drums (2200 lb).
   c. Citric acid, 8 drums (2000 lb).
   d. Alcohol (denatured), 340 gal.

2. Grind m-phenylenediamine. Grinding can be accomplished by two men in two days.

   a. Station hammer mill for grinding in a remote area and away from direct sunlight. Work from the windward side.

CAUTION: Grinders must wear protective clothing, including dust-proof pants, jacket (with hood), gloves, and respirator (dust-filtering).

CAUTION: The dust from grinding will blow with the wind and stain brown or black any object upon which it settles. Skin stain can be partly removed by the use of soap and water immediately after grinding. After it turns black it is permanent and must wear off.

   b. Feed the lumps into the hammer mill at a moderate rate.
   c. Cover the container of freshly ground "diamine" immediately after grinding.
   d. Use the "diamine" for preparation of Solution A as soon as possible after grinding. If allowed to stand for three to four days after being ground, it begins to decompose, releasing ammonia into the air and forming a tar. Sunlight accelerates the decomposition.

3. Ready the mixing equipment in the mixing area.

4. Start the steam tank car heater.

5. Connect the steam lines to heating pipes of the aniline tank aboard the Athey wagon.

CAUTION: Be sure there is no smoking and no flame in the vicinity for the remainder of the procedure.

6. Add all of the alcohol (340 gal) and half of the aniline oil (11 drums) to Tank A (aniline tank).

7. Turn the steam into the heating coils and heat to approximately 130 F and hold at about this temperature during the mixing. This temperature is slightly below the boiling point of alcohol.

8. Slowly add citric acid while stirring. Rapid addition causes caking of the citric acid. Use hand- or air-propelled stirrer.

CAUTION: Do not use any equipment which could cause a spark. Metal-to-metal contact must be avoided.

9. Add remaining aniline oil (11 drums). Stir. Be sure no lumps of citric acid remain on the bottom of the tank.

10. Allow to cool to ambient temperature.

11. Drain the completed solution into 55-gal steel drums, mark all drums "X-72, Solution A," and affix an "Inflammable" label.

CAUTION: In case of contamination of the body by either Solution A or Solution F, quickly flush off with large amounts of water. To completely remove residual amounts of chemicals, use large amounts of soap and water. Speed is very important in removing Solution A from the body.

SOLUTION F. Solution F (furfural) consists of 13 drums (6185 lb) of furfural and 5 gal of non-ionic wetting agent.

1. Add 1-2/3 qt of non-ionic wetting agent to each drum of furfural.

2. Mark all drums "X-72, Solution F," and affix an "Inflammable" label.

COMPLETED FORMULATION X-72. The 13 drums of Solution F (6225 lb) and 38 drums of Solution A (16,500 lb) comprise enough Formulation X-72 to stabilize one continuous 600-ft strip of beach sand,

12 ft wide and 6 in. deep, when using 6 per cent chemicals based on the weight of the sand.

PROCEDURE DURING OPERATION

The actual amphibious operation includes the following phases:

1. Loading the equipment and chemicals aboard an amphibious landing craft.

2. Loading the chemicals into the chemical tanks.

3. Unloading the stabilization equipment from the landing craft onto the beach.

4. Preparing the proposed road site.

5. Conducting the actual stabilization run.

6. Cleaning the equipment.

Loading and Landing Equipment

Loading or unloading the beach sand stabilization equipment using amphibious craft has not been attempted to date. The following suggestions, therefore, are given for consideration, but are untested operationally:

1. Use an amphibious landing craft for transporting and landing the equipment. An LCU (landing craft, utility) might be adequate for these purposes; the width of the Wood Roadmixer is such that a clearance of a few inches can be had on either side of the machine as it passes through the ramp opening in the bow of an LCU.

2. Skid mount the Wood Roadmixer on a heavily constructed platform long enough to protect the front and rear ends and drag it out of the LCU with the aid of a winch. Because of the length of the unit, it will "high-center" during unloading with consequent damage to the gathering wings or the vibratory compactor unless skid mounted.

3. Use extreme care to be sure that the Athey rig loaded with chemicals negotiates the ramp of the LCU or other landing craft without spillage or overturn. If time and circumstances permit, a safer procedure is to load the chemicals into the tanks after landing instead of before. (See Appendix III for emergency measures in case of accidental overturn of a chemical tank.)

Preparation of Site

Selection and preparation of the site for the proposed roadway should be done by members of the beach party under the direction of the Beach Party Commander or delegated authority prior to the landing of the stabilization team. Immediately after landing, see that the following measures have been taken or are taken:

RECONNOITER. Make a reconnaissance of the beach area immediately after landing to determine the best specific route for the roadway. The beach surface to be crossed should present a level, unloosened, unobstructed, uncluttered strip of sand.

AVOID SOFT OR LOOSENED AREAS. Soft or loosened areas do not offer a sufficiently firm base to support the chemically stabilized beach sand roadway. Initial failure of the roadway usually occurs in areas where it has been processed over loosened sand. The chemical sand mix produces a very hard roadway and where the roadway is processed over a loosened area adjacent to a firmer area, cracking will occur.

AVOID FILLS. Fills are certain to have soft or loosened areas which would allow the Roadmixer to sink slightly, thus causing the sand-gathering wings to scoop in excessive amounts of sand. This changes the ratio of chemicals to sand, giving a weaker mix.

AVOID GRADES. Excessive grades tend to stall the tractor towing and operating the Wood Roadmixer and will cause it to bog down.

REMOVE HUMPS. Level all humps transversely to the direction of the strip to be stabilized. Transverse leveling removes the hump without disturbing the surface to be stabilized from either approach side. If the hump is leveled along the path of the proposed roadway, the sand removed becomes part of a fill or loosened area, resulting in a faulty base.

CLEAN BEACH. Remove all barbed wire, planks, large rocks, and debris within six inches of the surface of the beach sand.

Any debris in the path of the stabilizing equipment will be incorporated into the stabilizing mix within the pug mill and cause damage. Cable, barbed wire, and steel rods can wrap around the helical spreaders and stop them. Planks, large rocks, and pieces of cable seldom pass beneath the hydraulic vibratory-compaction mechanism properly. These objects disrupt the screeding, producting large grooves in the roadway which can cause a buildup ahead of the vibratory mechanism, eventually producing an excessive drag load. Debris which passes beneath the vibrator can protrude at an angle from the roadway, becoming a traffic hazard.

Do not loosen the sand below six inches from the surface when removing debris from the path of the proposed roadway. Compact any loosened areas by repeated crossing with tractors.

Stabilization Run

Conduct the actual stabilization run in the following manner:

1. Get men and equipment in position for operation.

2. Lower sand-gathering wings, pug mill, and vibratory compactor.

3. Start operating stabilization equipment down roadway site.

4. Open chemical lines as soon as pug mill contains sand.

5. Continue to end of roadway site.

6. Notify the Beach Party Commander or other delegated authority, twenty minutes after successful completion of the final portion, that he can permit military traffic on the stabilized roadway.

PROCEDURE AFTER OPERATION

Cleaning Equipment

Perform the following cleaning operations as soon as possible after a stabilization run:

PUG MILL. Take the Roadmixer to a sand area and operate it without chemicals in a dry run through the sand. This will clean the inside of the pug mill and the base of the vibrator.

PUMPS. Clean the pumps by pumping fuel oil through the chemical feed lines, meters, and orifices. This flushing with fuel oil should be done very soon after a beach sand stabilization operation.

APPENDIXES

APPENDIX I

Some Possible Sources of Chemicals

The sources listed are indicative of the type of suppliers. They are by no means the only sources of the materials nor are they the recommended ones.

1. Aniline Oil:

   E. I. du Pont De Nemours and Company
   Organic Chemicals Division
   Wilmington, Delaware.

   American Cyanamid Company
   Calco Division
   Bound Brook, New Jersey.

2. Furfural:

   Quaker Oats Company
   Chemical Division
   333 N. Merchandise Mart
   Chicago 54, Illinois.

3. m-phenylenediamine:

   Same as for aniline oil.

4. Citric Acid (Synthetic, Anhydrous):

   Charles Pfizer and Company
   630 Flushing Avenue
   Brooklyn 6, New York.

   Stauffer Chemical Company
   636 California Street
   San Francisco 8, California

5. Wetting Agent (Non-Ionic Alkyl-Aryl-Poly-Glycol-Ether):

   a. Igepal-co-630 (or equivalent):

   Antara Products Division
   General Aniline and Film Corporation
   37 Clementina
   San Francisco 5, California.

   b. Triton X-100:

   Rohm and Haas Company
   Washington Square
   Philadelphia 5, Pennsylvania.

6. Alcohol (Denatured), Ethyl or Methyl:

   Publicker Industries, Incorporated
   1429 Walnut Street
   Philadelphia 2, Pennsylvania.

   Commercial Solvents
   260 Madison Avenue
   New York 17, New York.

   U. S. Industrial Chemicals, Incorporated
   60 East 42nd Street
   New York 17, New York.

APPENDIX II

Modifications Necessary to Wood Roadmixer

The commercial Model 54 Wood Roadmixer was designed to process an asphalt roadway. The experimental Laboratory Model 54-N which was used to develop and process the diamine modification of Formulation X-72 was obtained by modification of the commercial model. The following specifications were used as a guide for this modification.

Specifications for the Pettibone Wood Model 54-N Roadmixer, Serial Number 144

Capacity:	Up to 350 tons per hour, up to 1 mile per 8 hour day, 24 foot roadway, 3 inches thick.
Mixing Speeds:	1st speed: 12.0 feet per minute - standard on #144 2nd speed: 17.0 feet per minute - optional 3rd speed: 21.0 feet per minute - optional 4th speed: 24.0 feet per minute - optional
Tractor Drawn:	Caterpillar tractor D-8, I.H.C. TD-24, or Allis Chalmers HD-19
Pump Engine:	I.H.C. UD-14A

Athey Tracks to Replace the Standard Rubber Tired Wheels.

Oil Pump:	Two roper 3" number 5-A binder pumps so that two separate binders may be used.
Meters:	Two Neptune 2" - hot oil

Spray Nozzles:	Pettibone Wood Mfg. Co.
Hydraulic System:	Vickers and C. S. & S. high pressure four hydraulic cylinders - mixing drum one hydraulic cylinder - strike off blade two hydraulic cylinders - vibrator unit seven hydraulic motors five hydraulic control valves.
Vibrator Pan:	11' 6" wide with 300 inch vibrator and spreader attachment, Pettibone Wood Mfg. Co.

This roadmixer was modified per NAVCERELAB Contract N-1605-9343 dated 3-23-52 as follows:

Item 1 Main frame shortened from approximately 32 feet in length to approximately 23 feet.

Item 2 Mixer operator's platform re-positioned.

Item 3 Spreader attachment operator's platform re-positioned.

Item 4 Narrower fuel and hydraulic tanks fabricated and installed.

Item 5 Athey tracks moved forward as required and track hood cover installed.

Item 6 Main mixing drum & applicable hydraulic cylinders re-positioned.

Item 7 Spreader attachment moved forward to the most practical position possible.

Item 8 Engine position lowered and moved forward as required.

Item 9 Installed hydraulic pump and master clutch and provided oil-bath-type chain case for all hydraulic pump sprockets and chain.

Item 10 Provided separate clutches for binder pumps and provided oil-bath-type chain case for both pump sprockets and chain.

Photographs of the Laboratory Model 54-N Roadmixer (see Figure 16 - seven views) have been marked to show the changes and their location on the Roadmixer. The numbering is the same for all photographs. The features which are numbered are described according to numbers in the following list. Two items (No. 30 and No. 31) remained on the Laboratory modification but have no function during the chemical stabilization process.

1. Pressure gauge for Solution A, 0-100 pounds per square inch pressure, 5-inch dial.

2. Same item as (1) but for Solution F.

3. Discharge nozzle for Solution A, 3/16-inch slotted orifice, Pettibone Wood Manufacturing Company.

4. Same item as (3) but for Solution F.

5. Metal steps.

6. Close up of nozzle, 3/16-inch slotted orifice Pettibone Wood Manufacturing Co.

7. Vibrator pan, 11' 7" x 2'.

8. Rear operator's platform, 6' x 1' 6".

9. Track cover.

10. Spreading augers, 12-inch diameter, 12-inch pitch. Operate essentially as one auger which has been cut in two at the center. Each half operates individually and is reversible. One-half is a left hand pitch and the other half is a right hand pitch.

11. Mixer operator's platform.

12. Length of Model 54-N Roadmixer, 24 feet (approximate).

13. Height of Model 54-N Roadmixer, 9 feet (approximate).

14. Signal horn.

15. Metal steps.

16. Depth gauge, used in measuring the 6-inch cutting depth for the gathering wings (No. 29).

17. Pressure relief valve used to control discharge pressure of the chemical solutions, "W and McD" 2-inch, manual adjustment.

18. Fittings provided for use of pumps as transfer pumps.

19. Strainers for chemical solutions, 4-inch, Pettibone Wood Manufacturing Co.

20. Meters, "Neptune" 2-inch, totalizing, for use in measuring the quantity of flow of the chemical solutions.

21. Control valves 2-inch, plug-type.

22. Suction fittings, provided for using pumps as transfer pumps (e.g., emptying aniline and furfural barrels during loading).

23. Control valves, "Commercial," multiple unit, hydraulic, Model H-1320.

24. Vibrator, 300-inch, Pettibone Wood Manufacturing Co.

25. "Vickers" hydraulic motor drive for spreading augers.

26. Auxiliary engine to drive pumps, vibrator and hydraulic cylinders (used in raising and lowering equipment). UD 14A "International," with clutch to control hydraulic system and with pumps driven from front take-off with clutch on each pump.

27. Drive shaft for pug mill.

28. Hydraulic pumps for driving hydraulic motors.

29. Gathering wings.

30. Asphalt heaters - not required on Model 54-N.

31. False hub should be removed to reduce width of vibrator.

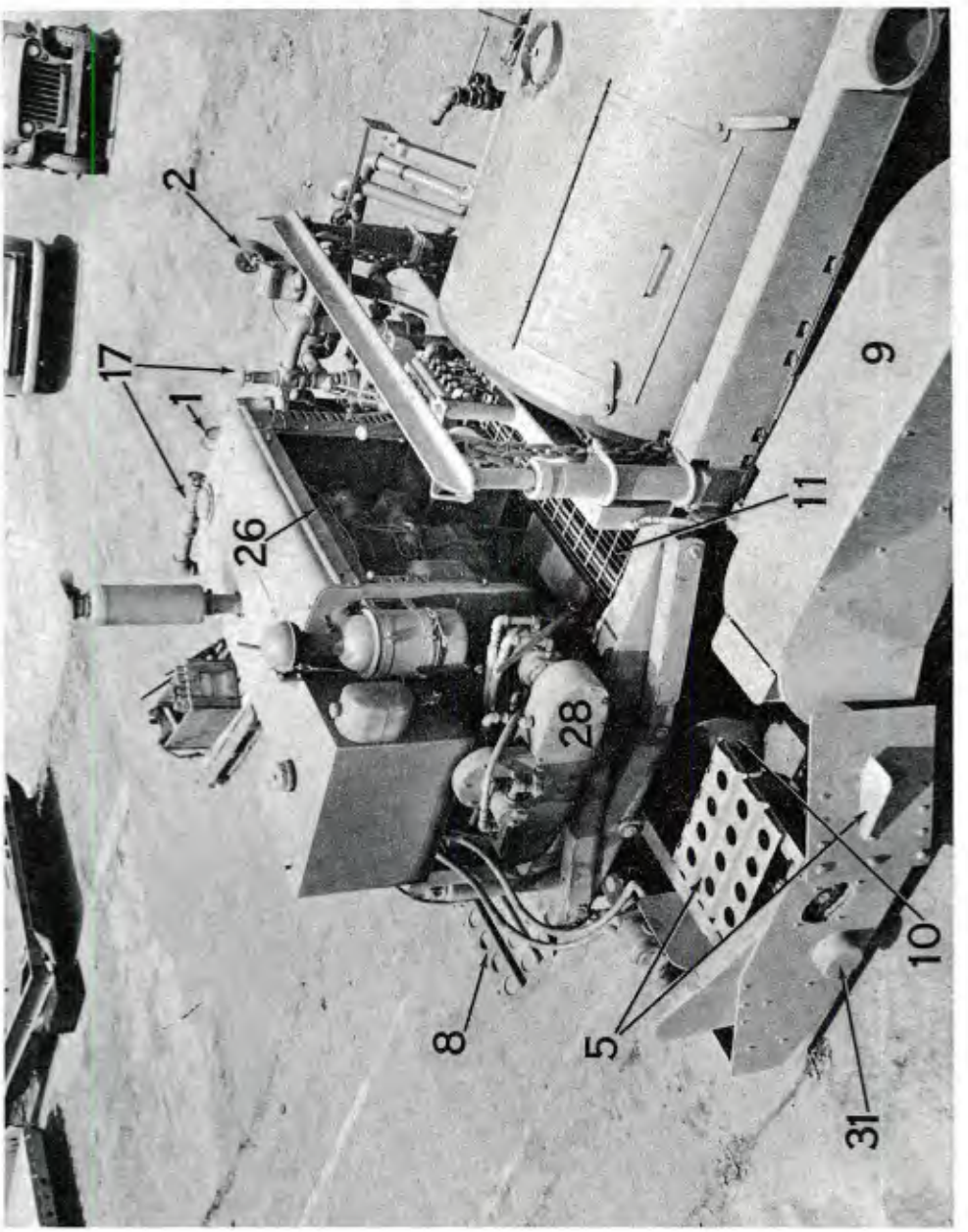

Figure 16. Laboratory Model 54-N Roadmixer (view 1).

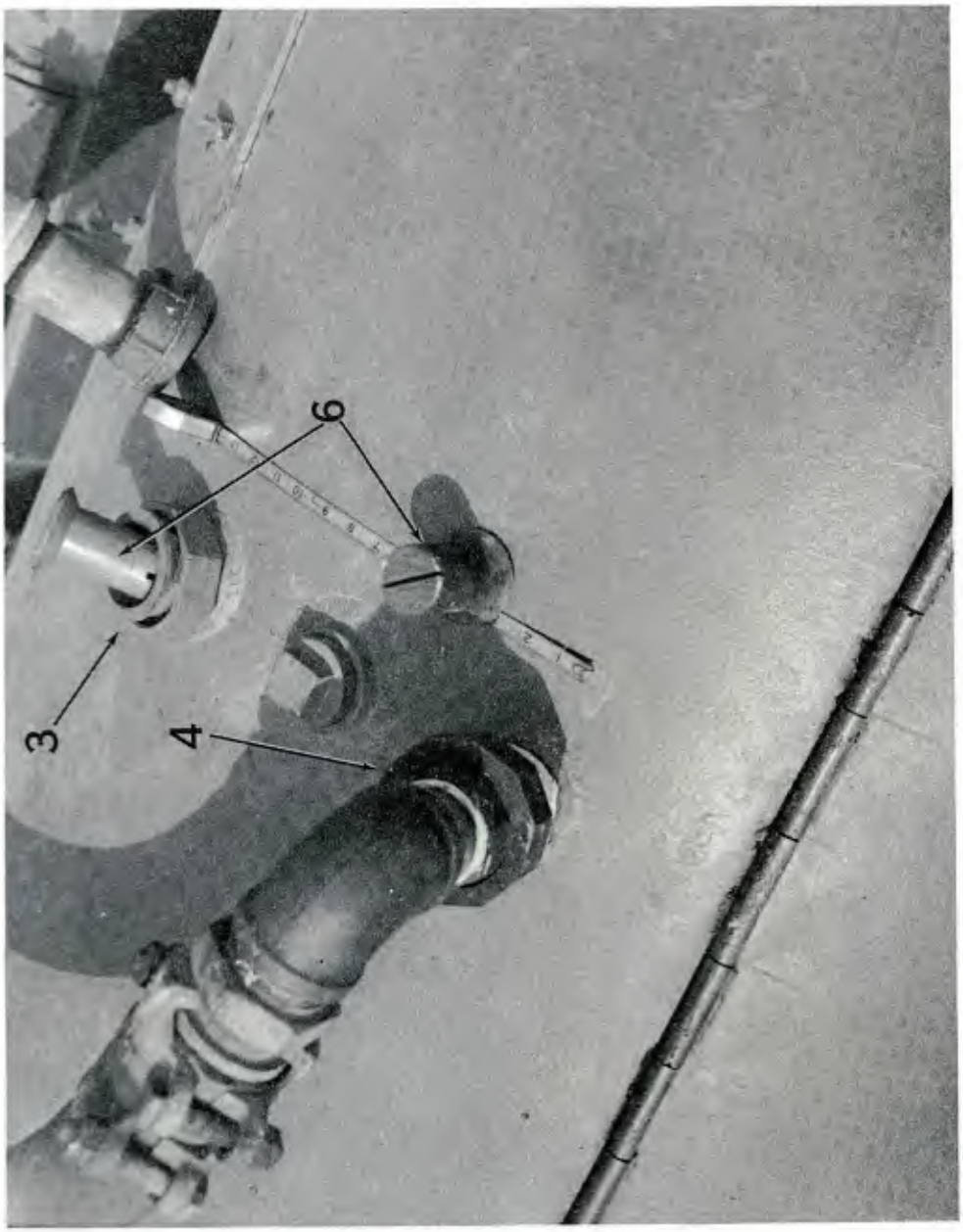

Figure 16. Laboratory Model 54-N Roadmixer (view 2).

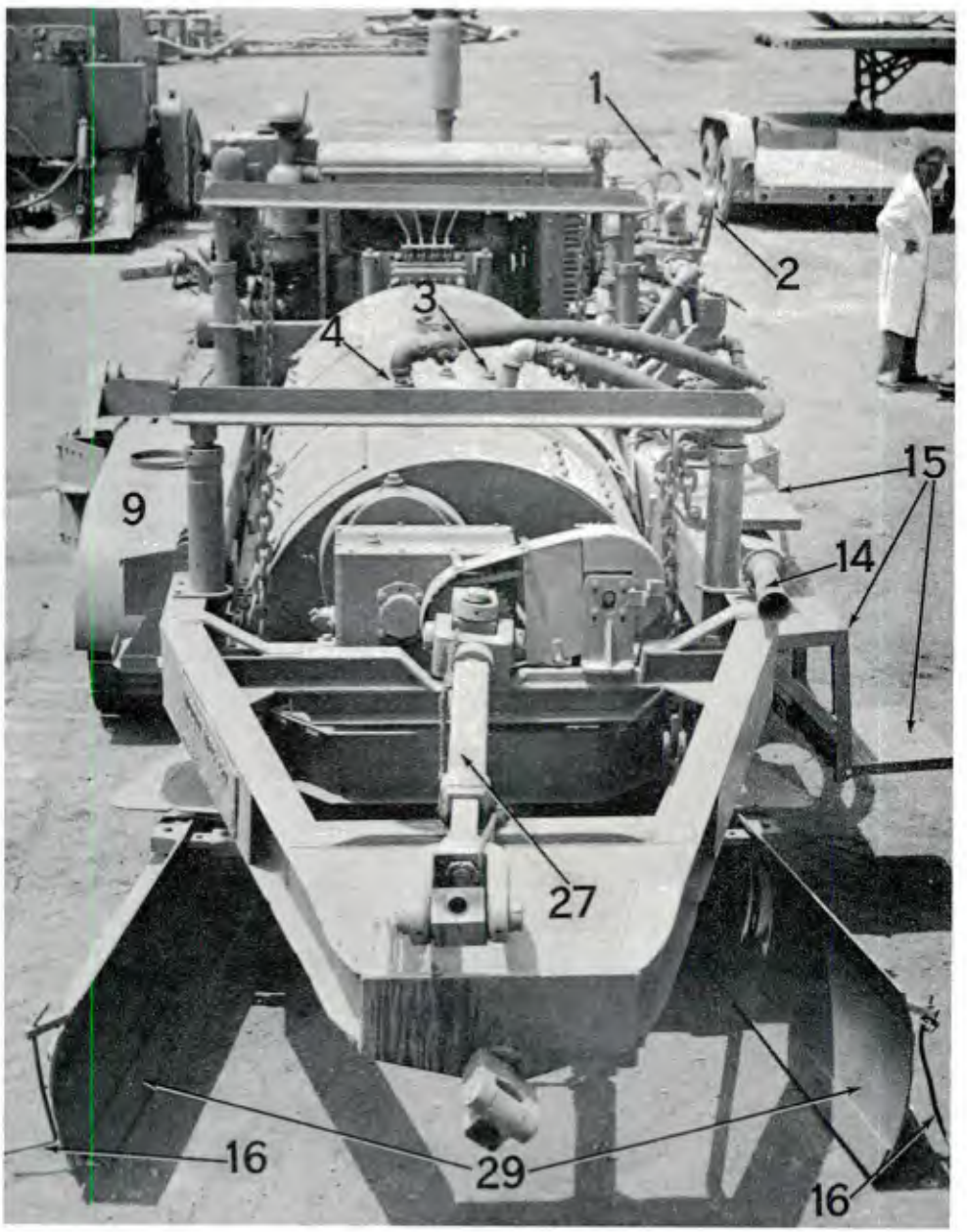

Figure 16. Laboratory Model 54-N Roadmixer (view 3).

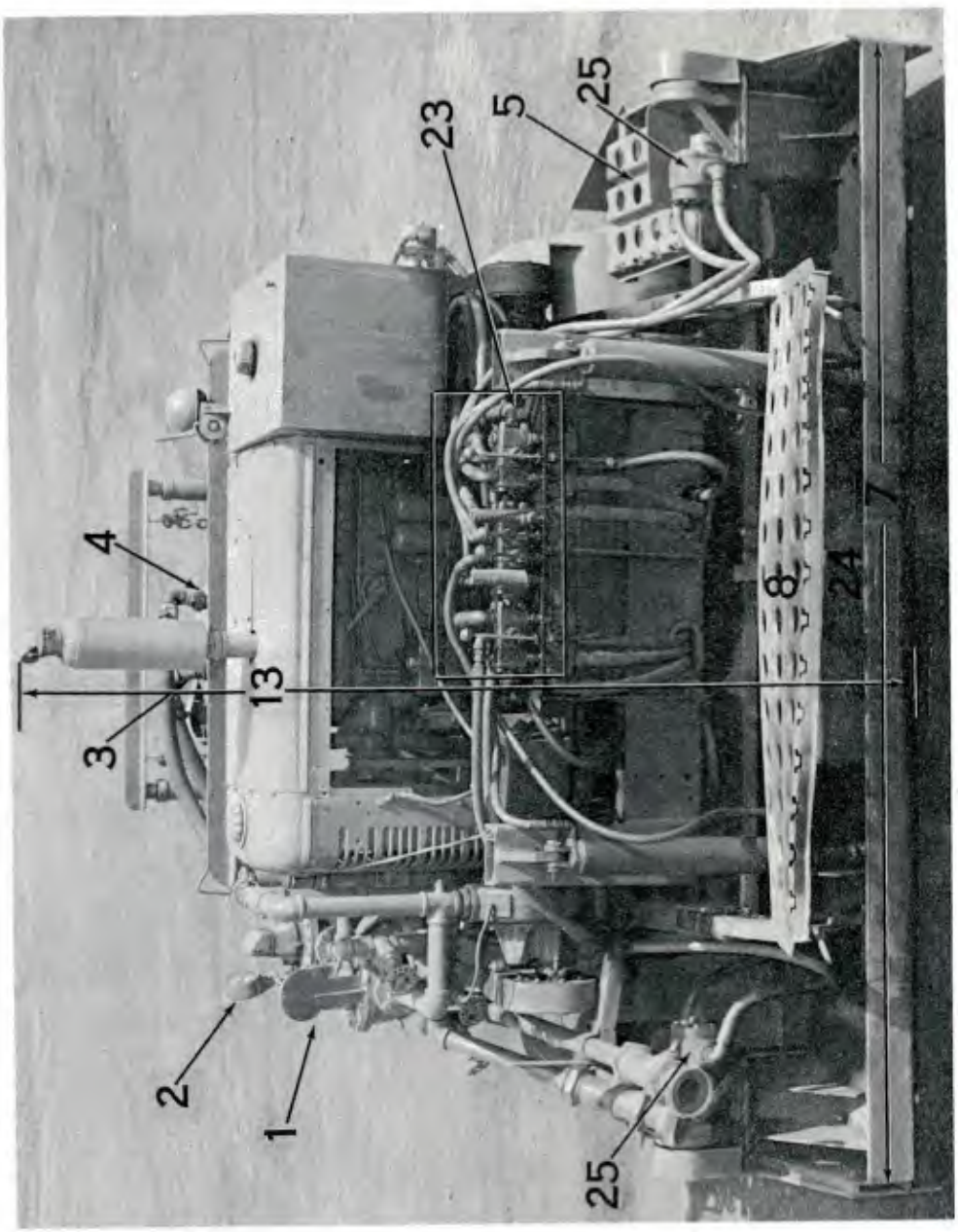

Figure 16. Laboratory Model 54-N Roadmixer (view 4).

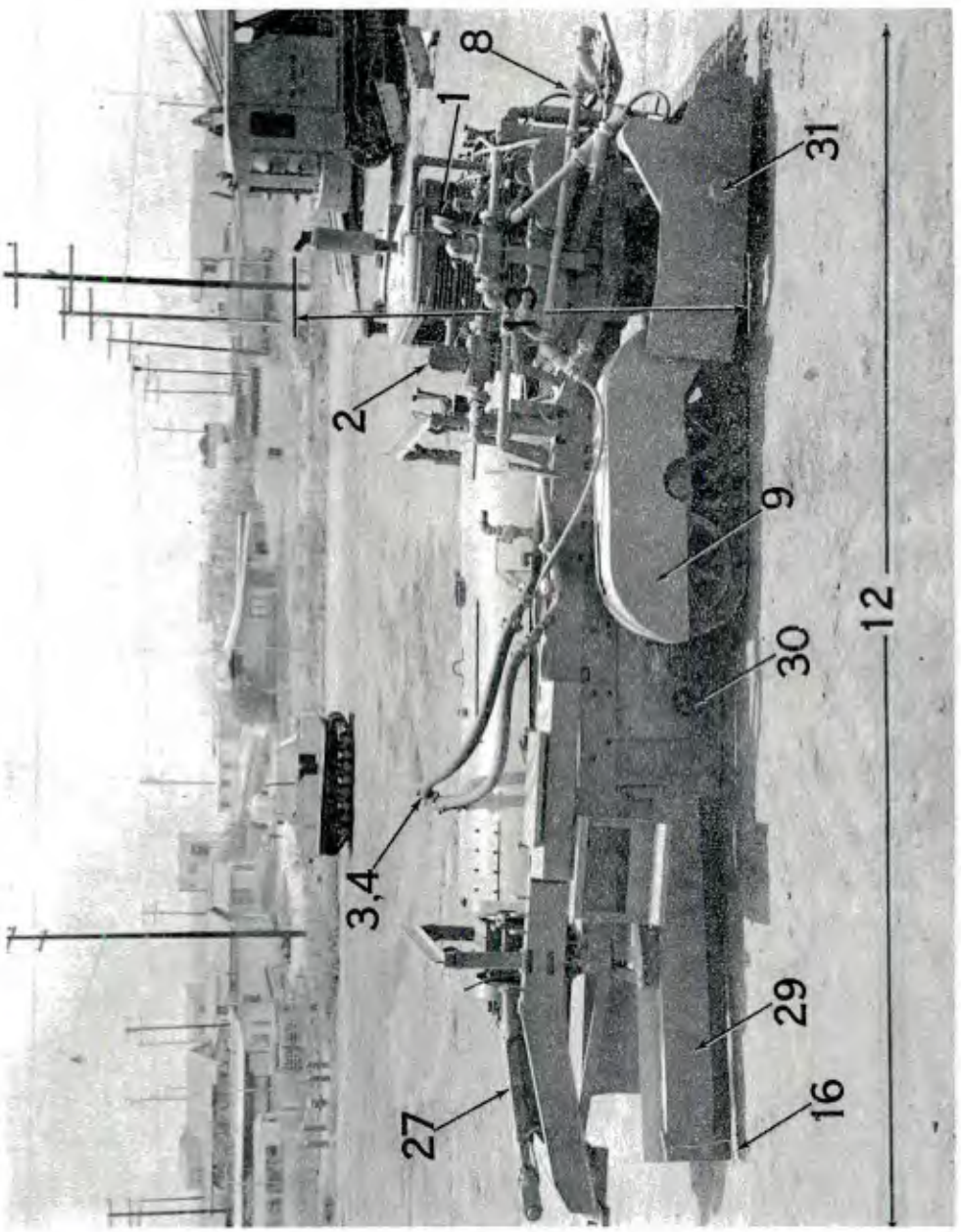

Figure 16. Laboratory Model 54-N Roadmixer (view 5).

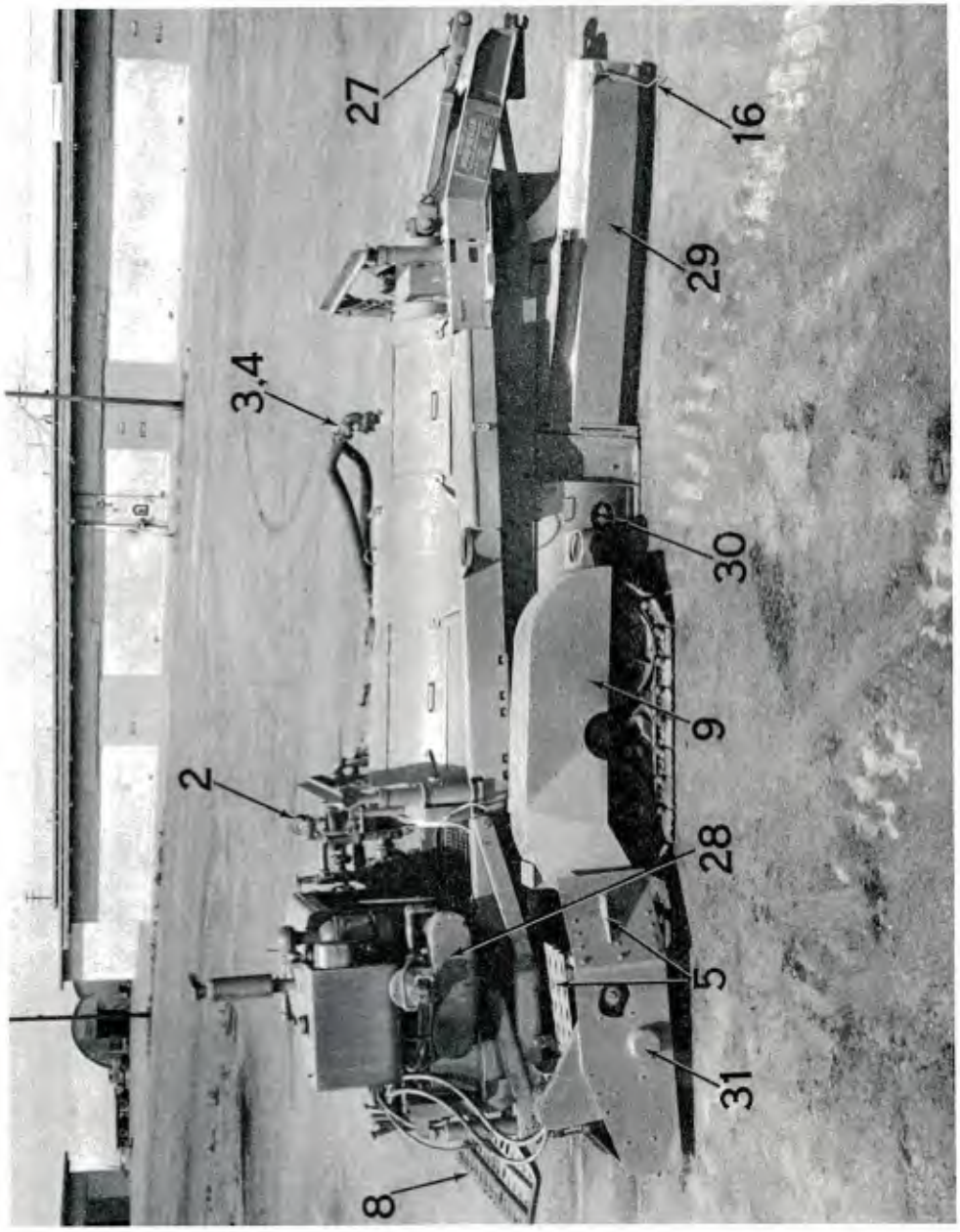

Figure 16. Laboratory Model 54-N Roadmixer (view 6).

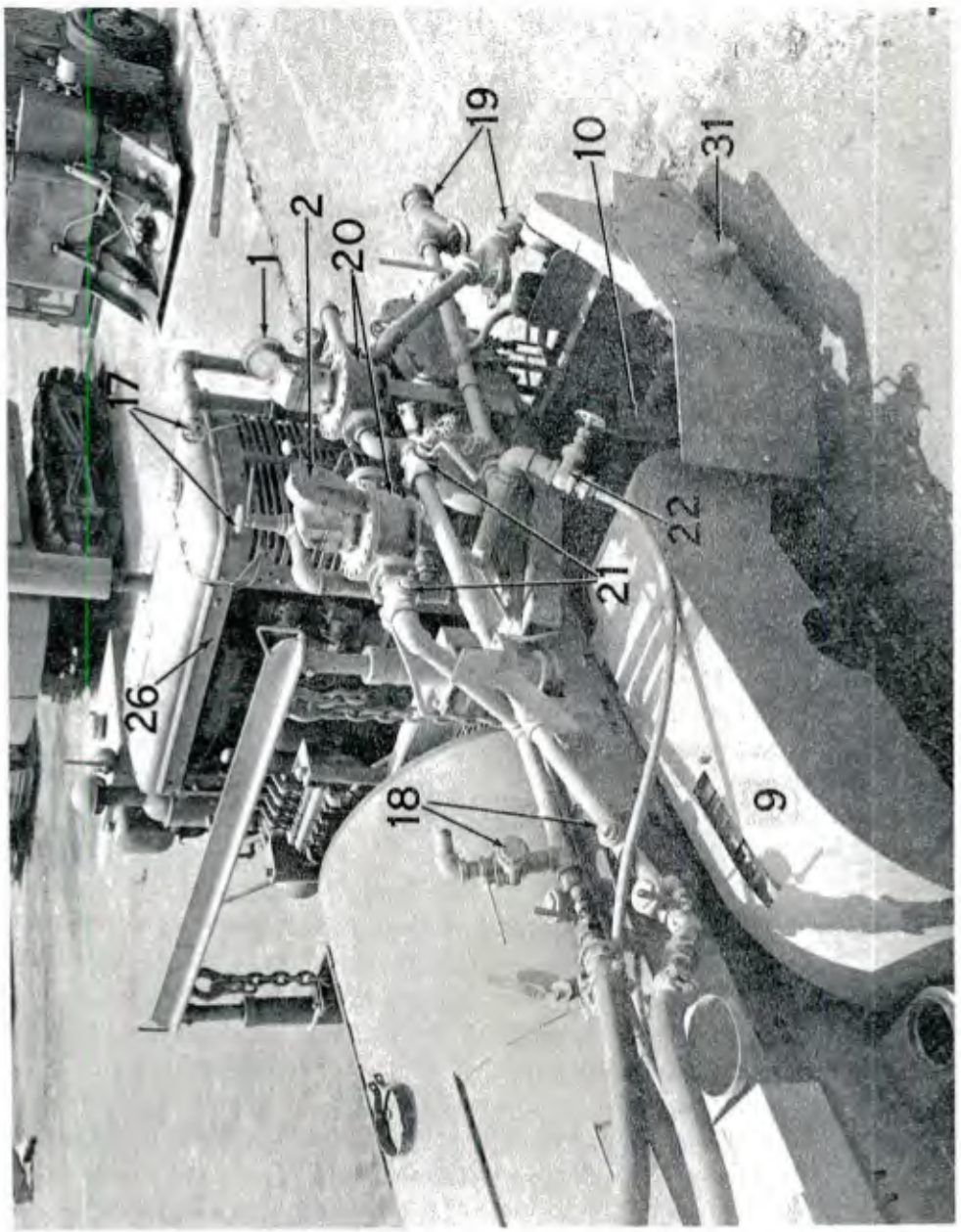

Figure 16. Laboratory Model 54-N Roadmixer (view 7).

APPENDIX III

Hazardous Properties of Chemicals

The following quotations are from Handbook of Dangerous Materials by N. Irving Sax, Reinhold Publishing Corporation, New York 18, N. Y. (1951).

1. ANILINE

Maximum Allowable Concentration in Air: 5 parts per million.

Hazardous Properties: Aniline is poisonous when absorbed through the skin, as well as by inhalation of vapor and dust, or by ingestion of dust upon saliva or food. Clothing which has been wet with aniline and in contact with the skin can often carry aniline into the body. The material is dangerous to the eyes. It is not dangerously reactive, but merely a health hazard. It affects the nervous system and the blood, causing fatigue, loss of appetite, headache, vertigo, disturbances of speech, as well as a variety of urinary manifestations. Absorption of aniline in toxic quantities causes cyanosis; an early symptom of this type of poisoning is a sense of well being, which develops into headache, drowsiness, etc. The maximum concentration which can be tolerated for 1 hour without serious symptoms is 100 to 150 ppm. Aniline is a flammable liquid and a moderate fire hazard.

Treatment and Antidotes: If proper treatment is not instituted at once, needless deaths may occur. Contaminated clothing should be removed quickly; speed in removing aniline from contact with the skin is of paramount importance. This should be followed by an immediate shower, using plenty of soap and warm water. Patient should then be carried to a first aid station for care and observation. If aniline has splashed into the eyes, they should be flushed with copious amounts of warm

water for at least 15 minutes. If taken internally, emetics should be given at once (mustard and water, emulsion of soap and water). The stomach syphon may be used; also cold effusions, stimulants such as ammonia, fresh air, and oxygen. Artificial respiration may be resorted to if breathing stops. Also give plenty of milk or black coffee, but no alcohol or castor oil. Get medical advice.

Storage and Handling: Aniline is combustible, although if safety rules are followed, there is little danger from that aspect. Store away from areas of acute fire hazards and preferably in the open. Any electrical equipment in such a storage area should be installed in accordance with the recommendations of the proper authorities. Great heat will cause aniline to give off toxic and flammable vapors. This must be borne in mind when fighting aniline fires or fires near where it is stored. Personal protective equipment is not considered sufficient for protection or a safe substitute for healthful working conditions where aniline is concerned. Suggested protective measures would include chemical safety goggles for exposed persons, as well as rescue harness and life line for those entering tanks and other enclosed areas. These measures should be used in conjunction with self-contained gas masks or positive-pressure hose masks, the hose inlet being in a vapor-free atmosphere. Rubber gloves, aprons, shoes, or boots should be worn. Coveralls and underwear should be provided. Great care should be taken to avoid contact of aniline and the skin. To fight fires of this material, foam, carbon dioxide, carbon tetrachloride, and dry chemical are recommended. Avoid use of water.

Shipping Regulations: Poison B No exemption Poison label 55 gal (max. lot).

2. M-PHENYLENEDIAMINE

Hazardous Properties: Of the 3 phenylene diamines, the para form has proved to be an especially powerful skin irritant. The salts are a nonirritant in contact with the unbroken skin, but hypodermic and gastric

administration of this substance produces a peculiar specific edema of the face, nose, tongue, conjunctiva and neck. This material is also responsible for asthmatic symptoms and other respiratory symptoms of workers in the fur dye industry where it is commonly used. These symptoms are due to direct irritation and bronchial stimulation, rather than to anaphylaxis. The para form will cause keratoconjunctivitis, swollen conjunctiva, and eczema of the eyelids. Systemic poisoning from this material is uncommon. At least one fatal case of liver involvement due to the para form has been reported in the literature. Meta- and ortho-phenylenediamine are somewhat less toxic than the para isomer. All forms are flammable and moderate fire hazards.

Treatment and Antidotes: If removal from exposure is prompt, the symptoms will be relieved. If the exposure has been severe, a physician should be called at once. If the material has come in contact with the eyes, mucous membranes, or the skin, the contaminated area or the involved skin areas should be washed promptly with plenty of lukewarm water and soap.

Storage and Handling: Personnel exposed to this material should wear protective clothing. Recommended are protective clothing to avoid contact with the skin, and chemical safety goggles to protect the eyes, if the concentration is high. Finally if personnel have been found sensitive to this material in concentrations in which it is being used, a respirator is indicated. To fight fires of this material use water (fog or spray), carbon dioxide, or dry chemical.

3. FURFURAL

Explosive Limits: 2.1 per cent by volume in air is lower limit of flammability.

Hazardous Properties: The liquid is dangerous to the eyes and is also a moderate fire hazard. The vapor is an irritant to mucous membranes and is a central nervous system poison. However, its low volatility reduces its toxic effect. Furfural which has been ingested has produced cirrhosis of liver in rats.

It is considered to be 63 times as narcotic as ethyl alcohol when tested upon goldfish. In industry there is a tendency to minimize the danger of acute effects resulting from exposure to it. This is true, particularly, because of its low volatility. Nothing much is known concerning the possibility of chronic effects, such as nervous disturbances, following prolonged or severe exposure to this material.

Storage and Handling: It should be stored in a cool well-ventilated place away from areas of acute fire hazard. Personnel who must be exposed to this material should wear protection for their eyes. Suggested are cup goggles, individual right and left plastic eye-cups, rubber-bound, indirect ventilation, adjustable fixed bridge, clear plastic lens at least .060 in. thick. To fight fires of this material, water (fog or spray), foam, carbon dioxide, carbon tetrachloride, and dry chemical may be used.

4. DENATURED ALCOHOL

The impurities placed in alcohol as a denaturant are many times more toxic than the alcohol itself. Methyl or wood alcohol used as a denaturant can cause blindness.

To quote from the Sax handbook:

a. Ethyl Alcohol

Maximum Allowable Concentration in Air: 1,000 parts per million

Explosive Limits: 3.5 to 19 per cent by volume in air.

Hazardous Properties: Ethyl alcohol is a dangerous fire hazard. It is also irritating to the eyes and upper respiratory tract. When ingested repeatedly in stronger forms, it is an irritant, particularly to the lining of the stomach, and can be paralyzing to the respiratory center.

Storage and Handling: Store in a cool place away from areas of acute fire hazard or open flames. Containers should be kept closed and plainly labelled. Personnel who must be exposed to high concentrations of the vapors or to splashes of the liquid,

should wear protective equipment. Recommended are a respirator of an approved design and chemical safety goggles. Generally speaking, good ventilation is all that is required for its safe use. To fight fires of this material, carbon dioxide, carbon tetrachloride, and dry chemical may be used. Avoid use of water.

Note: For mixtures of ethyl alcohol in water varying from 96 per cent ethyl alcohol to 5 per cent ethyl alcohol the flash points range from 62 to 144 F.

Shipping Regulations: Red label.

b. Methyl Alcohol

Maximum Allowable Concentration in Air: 200 parts per million.

Explosive Limits: 6.0 to 36.5 per cent by volume in air.

Hazardous Properties: A flammable liquid and a dangerous fire hazard. Though not dangerously reactive, it is toxic. Ingestion or absorption of methanol causes central nervous system damage, particularly of the optic nerve. It causes degenerative damage to the kidneys, liver, heart and other organs, which go on regardless of its portal of entry into the body. Blindness has occurred in a large percentage of cases of severe poisoning from this material. It affects both eyes, may set in within a few hours, or may be delayed for several days, due to injury of the optic nerve and retina; in many cases it is permanent. Workers who use this material may complain of local irritation of the eyes, skin and respiratory tract even when exposed to low concentrations.

Inhalation of excessive amounts of this material will result in acute poisoning within a short time. 1,000 ppm can cause slight symptoms of poisoning. 5,000 ppm can cause stupor and sleepiness, whereas 50,000 ppm will cause profound and probably fatal narcosis in from one to two hours.

Treatment and Antidotes: For first aid to a patient who has been exposed to this material, speed is of great importance. Immediately remove him

to fresh air, remove contaminated clothing and wash the body with soap and water. If this material has been swallowed, the stomach must be emptied as quickly as possible. If breathing has stopped, start artificial respiration. Keep patient quiet, comfortably warm, but not hot. Call a physician. If the eyes are involved, they should be washed immediately and copiously with water for a minimum of 15 minutes. For any of the chronic symptoms of exposure to this material, get medical advice.

Storage and Handling: This material should be stored in a cool place away from areas of acute fire hazard and open flame. Containers should be kept closed and plainly labelled. It should be stored in a ventilated area so that small leaks cannot build up enough concentration of vapor to cause explosions or the intoxication of individuals who enter such an area.

Personnel who are exposed to it should wear chemical safety goggles and a full face shield for protection of the face and eyes, and if the concentration of the vapor is high or unknown, a respirator should be worn to avoid excessive inhalation.

Shipping Regulations: Red label.

5. CITRIC ACID

Hazardous Properties: This material has been known to cause allergic symptoms in humans.

Storage and Handling: Exposed personnel who are sensitive to it should wear protective clothing, if necessary, to avoid bodily contact.

6. PREPARATION OF CHEMICAL SOLUTIONS

The preparation of the aniline solution without proper facilities is a hazardous operation, always accompanied by the possibilities of fire and acute poisoning of personnel. It is highly recommended that the aniline solution be commercially prepared and supplied in 55-gal drums.

The furfural solution, which contains only furfural and a liquid non-ionic wetting agent, can be prepared at the loading site or at any convenient place. These two liquids do not require prolonged mixing, but only addition of one to the other and slight stirring.

7. OVERTURN OF CHEMICAL TANK

Every precaution should be taken to avoid overturning an Athey rig or chemical tank full of the chemical solutions. In case of such accidental overturn, the following emergency measures should be taken immediately:

a. REMOVE ALL PERSONNEL at once to windward, because of the toxic nature of the solutions and fumes.
b. COVER THE SOLUTIONS by having bulldozers push sand over them from the windward side.
c. EXTINGUISH FIRE with carbon dioxide, dry chemical, or carbon tetrachloride and sand, if any should develop.
d. TAKE PERSONNEL PROTECTIVE MEASURES as listed for the individual chemicals.

APPENDIX IV

Alternative Method of Beach Sand Stabilization (S-1 Formulation)

Formulation S-1. During the chemical research a second formulation, designated S-1, was developed which would stabilize beach sand but was not as easily processed into the sand as X-72. The catalyst used in Formulation S-1 is a dry component not soluble in the aniline or furfural solution and therefore would necessitate processing three components compared to two components for X-72. A dry-spreader would be required to distribute the dry component onto the beach sand ahead of the Wood Roadmixer. Beach sand stabilization using this method would require equipment not yet developed, therefore it has not been tested operationally. Formulation S-1 is included here for purposes of comparison.

Equipment. The stabilization equipment employed is the same as for Formulation X-72.

Chemicals. The following chemicals are required for stabilizing 600 feet of beach sand:

Aniline oil	14,400 gal
Furfural	660 gal
Wetting agent . . .	5 gal
Sulfanilic acid . . .	1800 lb

The only chemical mix preparation required is the addition of the non-ionic wetting agent to furfural in the same quantities as for Formulation X-72. Aniline oil is used instead of aniline mix. Aniline oil requires no previous preparation or admixing and its storage life is indefinite.

Procedure.

1. The Athey rig (chemical tanks) is loaded with 12,120 lb (27 drums) of aniline oil in the aniline tank and 5940 lb

(12 drums) of furfural and 5 gal of the non-ionic wetting agent in the furfural tank.

2. The chemical flow is metered as follows: aniline oil - 24 gal per 10 ft. Furfural solution - 11 gal per 10 ft.

3. The sulfanilic acid is distributed on the sand along the path of the proposed roadway at the rate of 6 lb per ft.

4. The Wood Roadmixer is operated over the windrow of sulfanilic acid.

5. Traffic loading is permissible after about 30 minutes.

Temperature. Temperature considerations are the same for Formulation S-1 as for Formulation X-72. The aniline oil and furfural require some heating if the temperature of the sand is below about 45 F.

Toxicity of Sulfanilic Acid. The sodium salt of sulfanilic acid is reported in the literature as relatively nontoxic.

CAUTION: Protection of the eyes from the sulfanilic acid dust is necessary. Wash exposed areas with soap and water.

Possible Source of Sulfanilic Acid. Powdered sulfanilic acid can be obtained from Calco Chemical Division, American Cyanamid Company, Bound Brook, New Jersey, or a similar supplier.

Cost. The cost of the chemicals required to stabilize a strip of beach sand 600 ft long, 12 ft wide, and 6 in. thick, is approximately $4000.00

APPENDIX V

Special Mixing Tank

Under emergency conditions where commercially prepared solutions cannot be procured, it is recommended that a special round-bottom tank of approximately 2200-gallon capacity, having a helical or paddle stirrer in the bottom and steam heating coils above the stirrer, be used for preparing the chemicals. During dissolution of the citric acid in the heated aniline-alcohol solution, thorough agitation and stirring are required as the acid tends to settle to the bottom and become compacted. The stirring mechanism must be sparkproof and any metal-to-metal contact which could produce a spark must be avoided.

The chemicals can be mixed in the pontoon tanks and stirred by hand, using a long metal pipe fitted with a flat blade for scraping the bottom of the tank, but this is hazardous. The position of the stirrer atop the pontoon tank is precarious because of insecure footing and the possibility of fire and toxic fumes.

DISTRIBUTION LIST

No. of copies	
15	Chief, Bureau of Yards and Docks (D-400)
5	Armed Services Technical Information Agency, Dayton, Ohio

Naval Civil Engineering Research and Evaluation Laboratory. Technical Memorandum M-096.
CHEMICAL STABILIZATION OF BEACH SAND, by C.V. Brouillette. 1 Dec 1954 (revised Sep 1956). 59 p. illus. UNCLASSIFIED

A description of the diamine modification of the aniline-furfural (Formulation X-72) method of producing roadways in beach sand is given. This memorandum was prepared for use by amphibious personnel and includes personnel requirements and safety precautions. An alternative formulation (S-1) is discussed.

1. Beaches - Stabilization
I. Brouillette, C.V.
II. NY 440 008

Naval Civil Engineering Research and Evaluation Laboratory. Technical Memorandum M-096.
CHEMICAL STABILIZATION OF BEACH SAND, by C.V. Brouillette. 1 Dec 1954 (revised Sep 1956). 59 p. illus. UNCLASSIFIED

A description of the diamine modification of the aniline-furfural (Formulation X-72) method of producing roadways in beach sand is given. This memorandum was prepared for use by amphibious personnel and includes personnel requirements and safety precautions. An alternative formulation (S-1) is discussed.

1. Beaches - Stabilization
I. Brouillette, C.V.
II. NY 440 008

Naval Civil Engineering Research and Evaluation Laboratory. Technical Memorandum M-096.
CHEMICAL STABILIZATION OF BEACH SAND, by C.V. Brouillette. 1 Dec 1954 (revised Sep 1956). 59 p. illus. UNCLASSIFIED

A description of the diamine modification of the aniline-furfural (Formulation X-72) method of producing roadways in beach sand is given. This memorandum was prepared for use by amphibious personnel and includes personnel requirements and safety precautions. An alternative formulation (S-1) is discussed.

1. Beaches - Stabilization
I. Brouillette, C.V.
II. NY 440 008

Naval Civil Engineering Research and Evaluation Laboratory. Technical Memorandum M-096.
CHEMICAL STABILIZATION OF BEACH SAND, by C.V. Brouillette. 1 Dec 1954 (revised Sep 1956). 59 p. illus. UNCLASSIFIED

A description of the diamine modification of the aniline-furfural (Formulation X-72) method of producing roadways in beach sand is given. This memorandum was prepared for use by amphibious personnel and includes personnel requirements and safety precautions. An alternative formulation (S-1) is discussed.

1. Beaches - Stabilization
I. Brouillette, C.V.
II. NY 440 008