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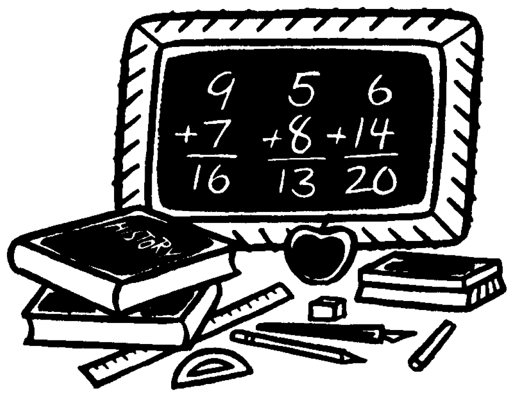

Lessons Learned from Design & Engineering of Naval Facilities

NAVFAC P-1010
October 1985

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CASE S1 - Failure of Precast Concrete Lintels, M. Yachnis

Problem: Failure of precast reinforced concrete lintels in a building which resulted in a great loss of money and construction time.

Symptoms: Extensive cracking on the bottom on the majority of the precast reinforced concrete lintels developed shortly after their placement over door and window openings (see Fig. 1). The first reaction was that the cause of cracks was either overloading or poor quality of concrete or inadequate reinforcement.

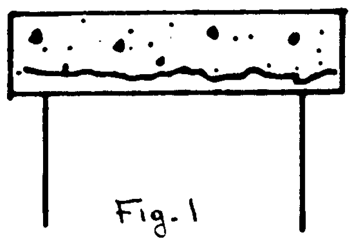

Fig. 1

Collection of Facts: This project involved a complex of multi-story apartment buildings with brick bearing walls, steel columns, beam and joists. A structural evaluation of the precast reinforced concrete lintels was made from the design drawings and they were found adequate to carry the design loads. During the investigation, it became obvious that the location of the reinforcement was unknown after the fabrication of the lintels. Therefore, a great number of lintels were placed over the openings with the reinforcement on the compression side of the lintel (The top of the lintel. See Fig.2). This was verified by removing a number of lintels and exposing their reinforcement. Removing the cracked lintels and replacing them with new lintels was a costly process since it was necessary to remove and replace part of the already constructed brick wall over the lintels.

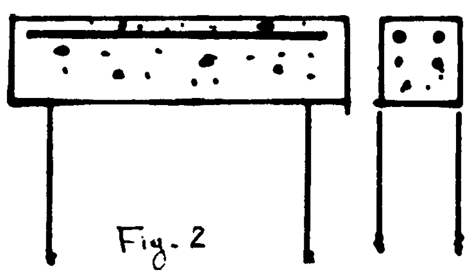

Fig. 2

Solution: Use top and bottom reinforcement in precast concrete lintels to eliminate the possibility of misplacement. See Figure 3.

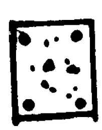

Fig. 3

CASE S2 - Overload of Roof Trusses, M. Yachnis

Problem: Overloading of roof trusses-storage building, Patuxent River.

Symptoms: A visual inspection showed excessive deflection of the roof trusses with indications of cracks and torsion at the bottom elements of the trusses. Measurements taken indicated deflections in excess of 2 inches.

Collection of Facts: A storage building located at NAS Patuxent River was designed with steel columns and roof trusses. A structural analysis was performed based on the original loading conditions. Stresses and deflections were found to be within allowable limits. Results of a material survey indicated that the trusses were maintained properly without evidence of corrosion or any other type of material deterioration. During the site survey it was found that various sizes of piping from 1 inch to 6 inches in diameter and heavy air conditioning units were supported by bottom elements of the truss (see Fig. 4). This additional loading was imposed on the trusses in various times after the original construction. A new structural analysis which included the additional loading substantiated the cause of distress.

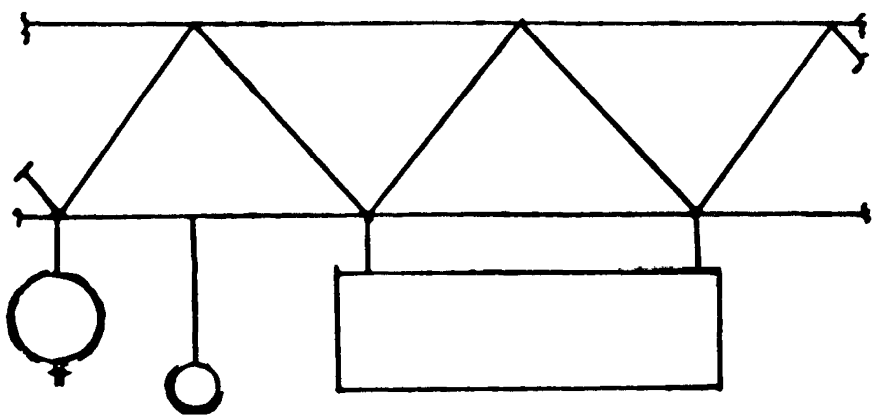

Fig. 4

Solution: To correct this situation, it was recommended that the additional loading be immediately removed from the bottom of the trusses. Secondly, a repair procedure was initiated to eliminate the imposed deflection and repair the damaged members. A very useful lesson to be learned from this case is to compare the original loading conditions with the existing conditions during the structural investigation. In many projects, alterations are made during the initial stages of construction which are not followed by preparation of as-built drawings. In these cases, a structural analysis based on original drawings and loading conditions will result in erroneous findings.

CASE S3 - Anchorage Failure of Wall Panels, M. Yachnis

Problem: Movement of precast concrete panels attached to the structural members.

Symptoms: After a few days of rain, accompanied by freezing temperatures, joints between the wall precast concrete panels opened up and the panels had moved outwards from their vertical position.

Collection of Facts: In July of 1975, the Chesapeake Division of the Naval Facilities Engineering Command (CHESNAVFAC) assisted by Code 04B, NAVFACHQ performed an engineering investigation of a potentially hazardous situation, It had been noted that some of the concrete exterior wall panels on Buildings 7 and 8 of the National Naval Medical Center, Bethesda, MD were misaligned and that the cause of their movement must be determined in order to prevent further deterioration of their condition.

The study uncovered several factors which contributed to the movement of the panels. In the original design, there was no adequate provision for the expansion of individual panels due to temperature change. Contraction and expansion of the panels caused the mortar joints between the panels to fail, allowing water to seep in. The expansion of this water upon freezing forced the panels to move outward to such a degree that some of the panel anchors failed, leaving the panels offset by as much as 2 inches (Figure 5). In other places, the l/8 inch wire panel anchors rusted through. In addition, it was discovered that many of the wire anchors had never been used at all. The possibility of these panels falling from the building posed a serious threat to the lives of pedestrians below.

It was estimated that the cost of replacing the existing panels with new ones was $1.5 million. However, NAVTAC and the Officer in Charge of Construction, Bethesda, MD, arrived at an alternative solution resulting in nearly $1 million in savings. The purpose of this case history is to describe the unique system of chemical anchoring used to repair these buildings, and to examine the feasibility of using this system for other engineering applications.

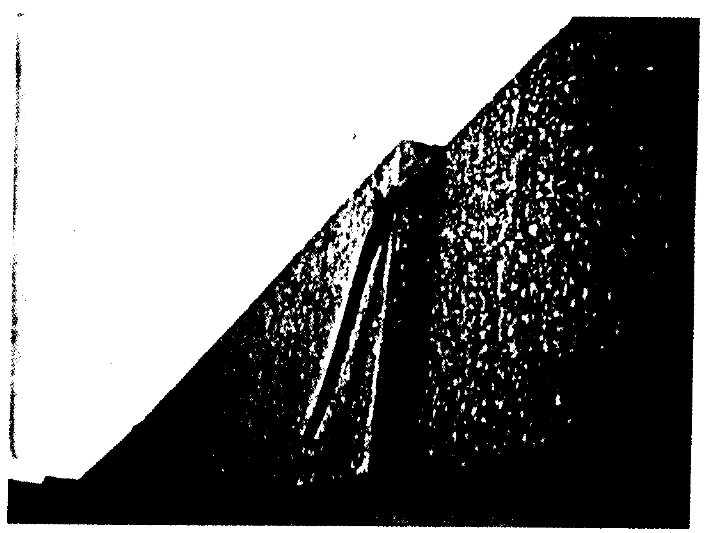

Fig. 5

Solution: The economical system decided upon by the Navy's engineers is one which consists of two components - a chemical anchor capsule and a threaded steel bolt (Figure 6). The hermetically sealed anchor capsule contains a premeasured ratio of polyester resin, quartz sand aggregate and a hardener. This glass capsule was inserted into a countersunk bore hole which had been drilled through the precast panel and into the interior concrete block wall (Figure 7). The bolt was hammered into the bore hole to smash the cartridge (Figure 8) and then a vibrating power drill was used to mix the contents into a resin mortar (Figure 9). A positive bond between the stud, the chemical anchor, and the surrounding wall material was assured by using the highest intensity vibratory setting and the lowest drill speed to mix the epoxy components thoroughly. The resin mortar was given time to harden and then the bolt hole was filled with grout to regain the original aesthetics of the building. Each panel required a minimum of two anchors to provide structural adequacy in accordance with AISC Paragraphs 1.5.1.4.3, 1.5.2.1, and 1.5.5 (Figure 10).

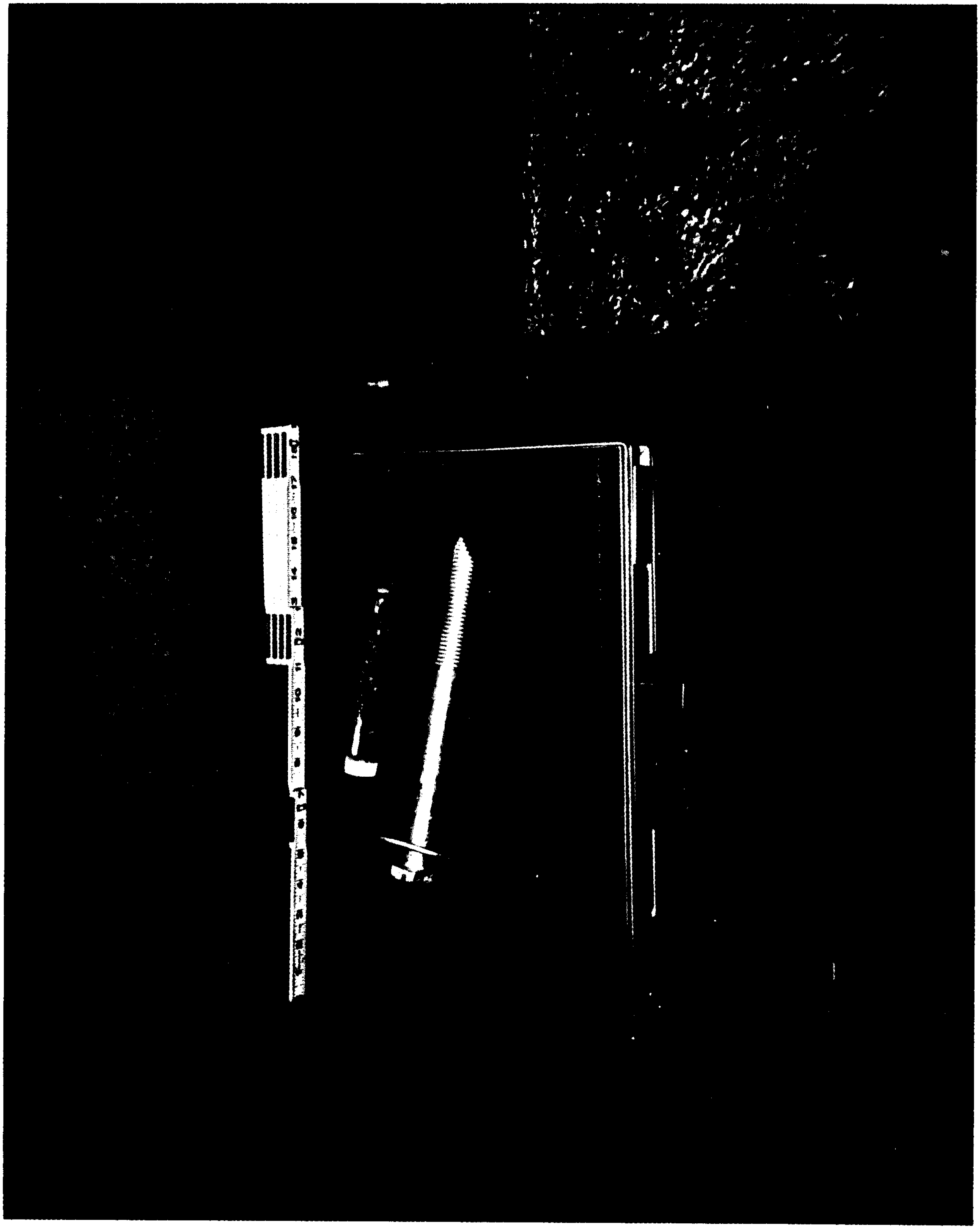

Fig. 6

Fig. 7

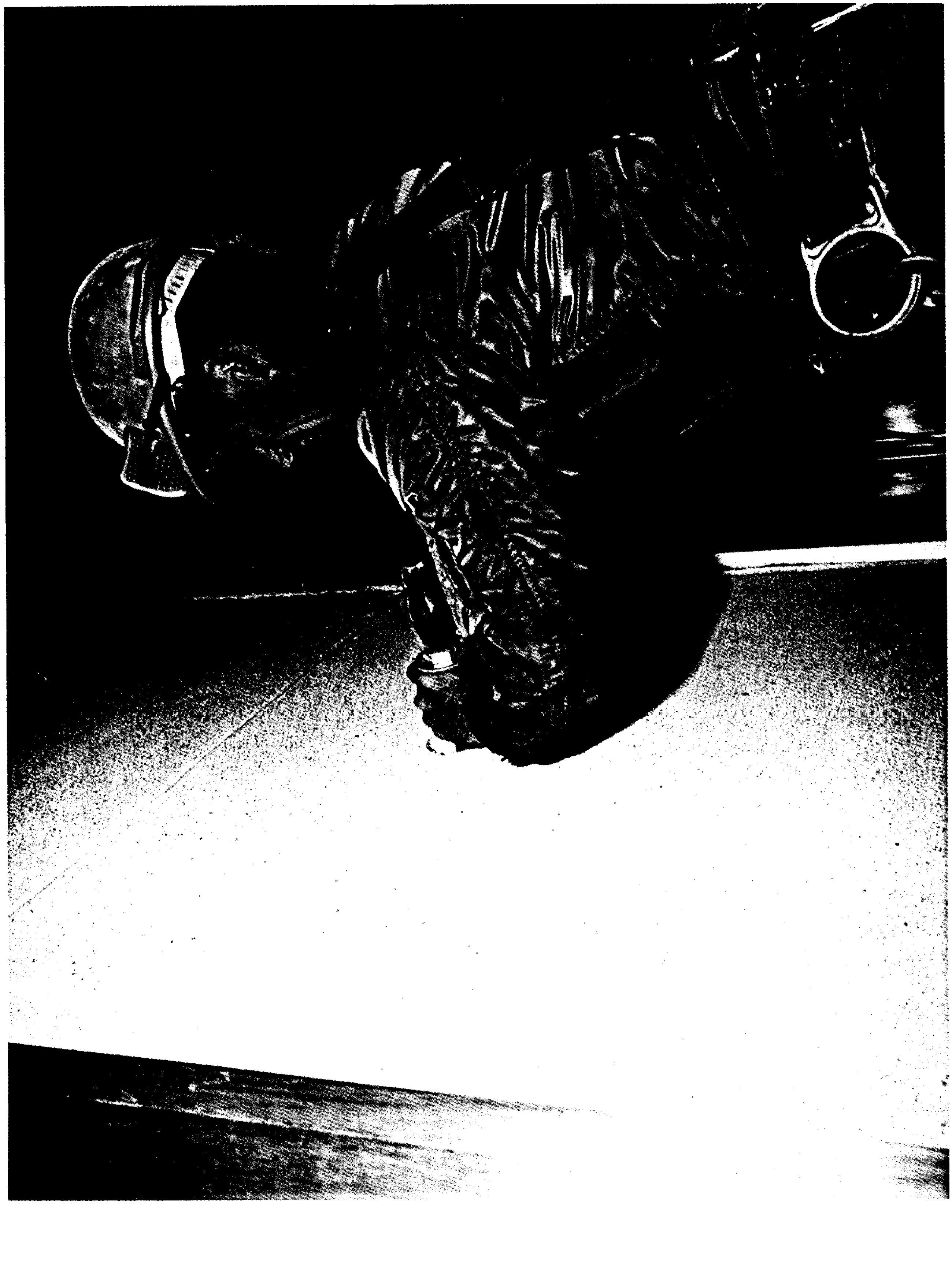

Fig. 8

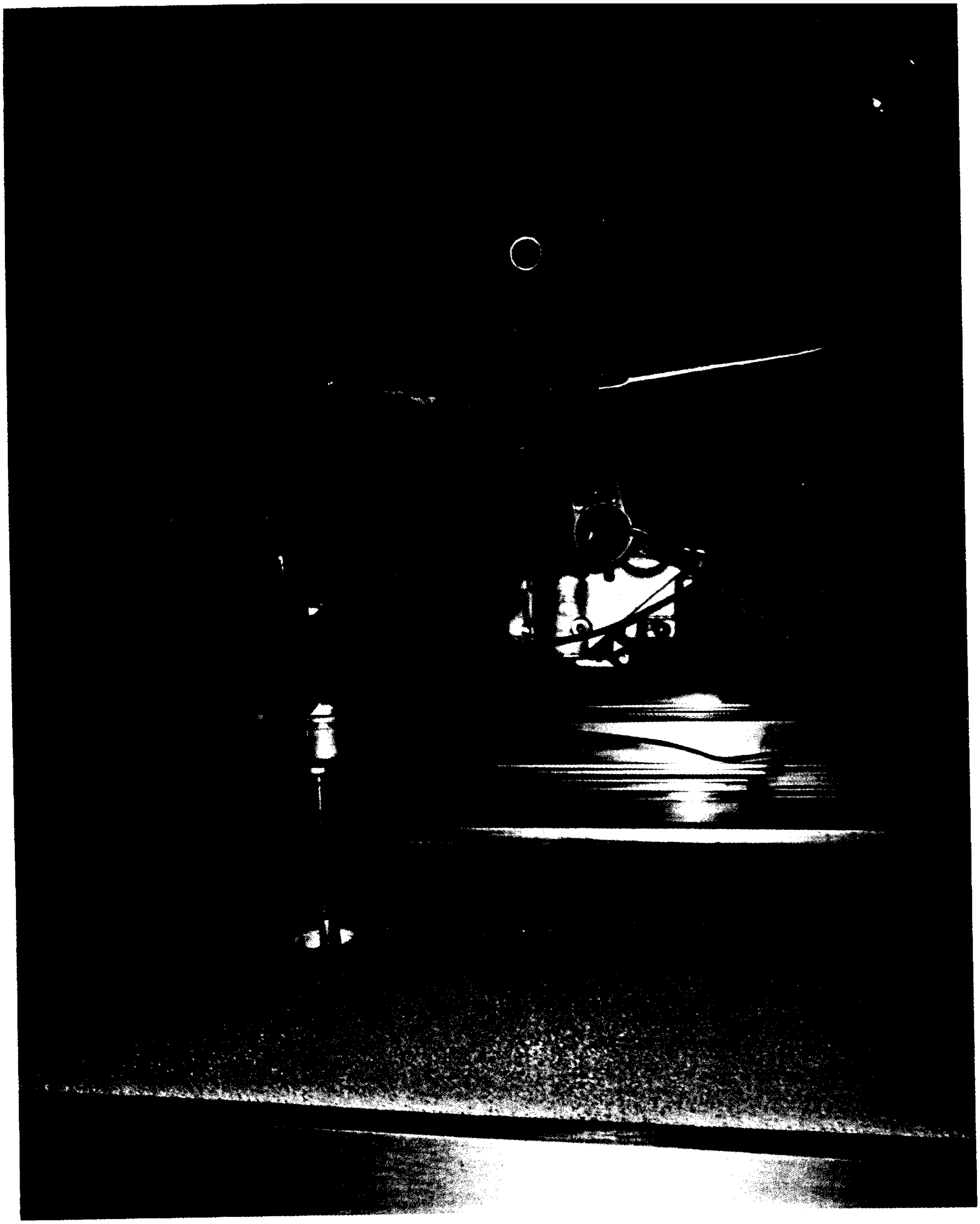

Fig. 9

Fig. 10

1. Advantages of the System

The chemical epoxy anchoring system was chosen because of the following distinct advantages it has over typical anchoring systems:

a. When an expansion anchor is used, the torquing required to fasten the anchor introduces stress into the panel which may result in damage or failure. The chemical anchor does not expand and therefore does not produce this excessive stress in the concrete.

b. Placement of the chemical anchor is unaffected by wet conditions. It may even be installed under water and the steel stud will not corrode in the bore hole.

c. The epoxy bonds effectively in a diamond bit drilled hole and pullout values of up to 55 kips (with dynamic invariance) may be obtained.

The above reasons combined with the fact that the installation of the system is fast and simple (the epoxy components are guaranteed to be correctly proportioned and will set in 30 minutes at 20°C (68°F)) made it desirable over all other systems considered.

2. Other Applications

The advantages of this unique system also make it useful for other applications. The resin cartridges were originally developed for use in mine roof bolting. A mining company in Pennsylvania has found that by using the chemical anchoring system, the time required for overcast construction in its mine advancing operations was reduced. The resin-grouted anchor bolt is used in combination with a spin-in bolt to assure horizontal control during blasting and to eliminate the need for rebolting the mine roof after blasting. Because of the strong bond developed between the bolt and the rock, the roof bolts are insensitive to blasting damage which may ordinarily result in the loss of bolt tension. Further, the chemical anchoring system does not have the problems of anchor creep and rock breakage around the bearing plate that mechanically anchored systems have.

The resin-grouted bolts may also be useful in anchoring the rails of Overhead Electric Traveling (OET) Cranes. Typically, the crane rails are supported by steel or concrete columns. However, an angle with stiffener plates could be anchored to a spandrel beam to achieve the same result at a lower cost (Figure 11). In situations where excessive crane loads would require impractical bolting schemes, the anchors may be used in combination with columns to substantially reduce the cost of the columns. This railing system would be very reliable because of the anchor bolt's extremely high pullout values and because it is unaffected by dynamic loading.

Underground steel fuel tanks subject to uplift due to hydrostatic pressure can be anchored by using the chemical anchoring system. Holes may be drilled through the bottom of the tank to grout the bolts into the concrete foundation below (Fig. 12).

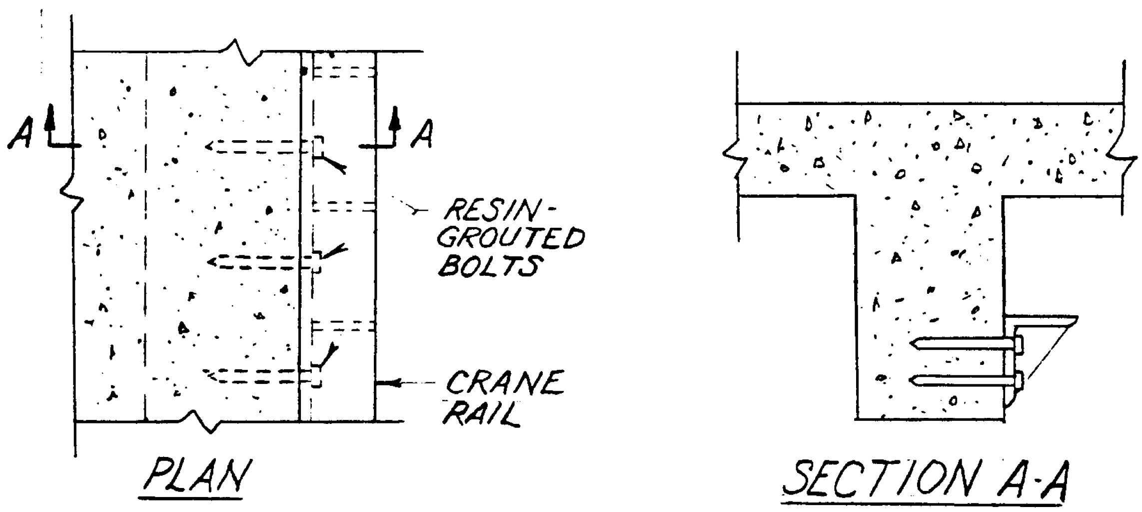
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Fig. 11

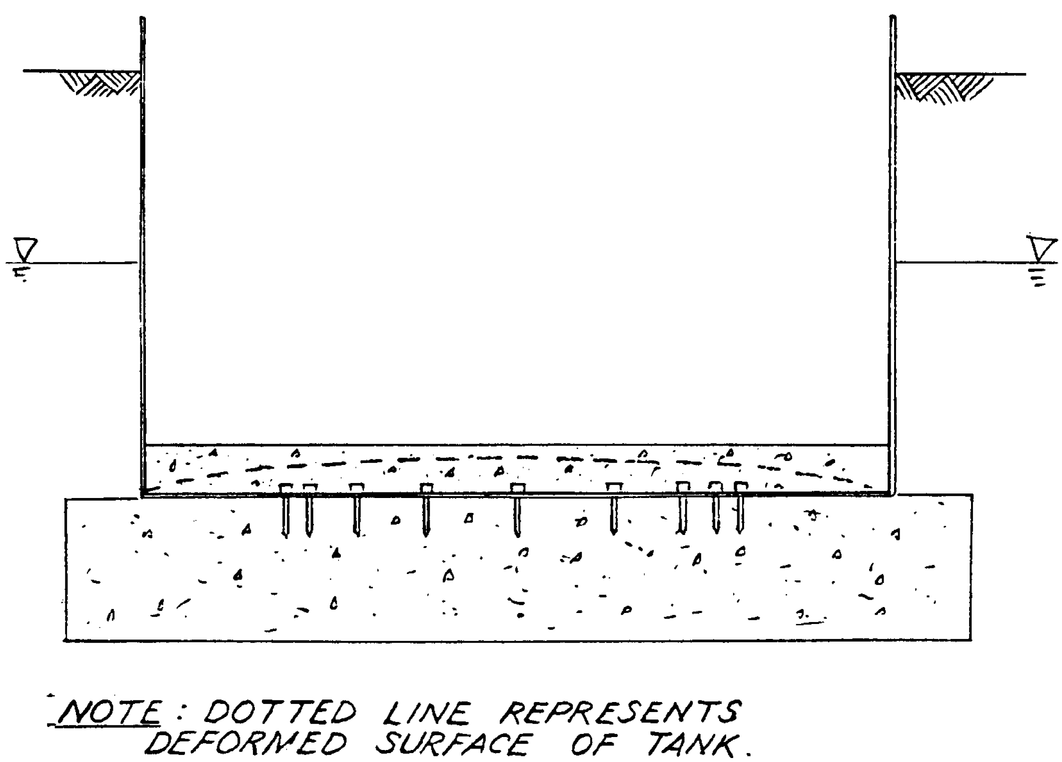

NOTE : DOTTED LINE REPRESENTS
DEFORMED SURFACE OF TANK.

Fig. 12

On a smaller scale, the epoxy grouted bolts could be used to anchor retrofit signs, flag poles, or lighting systems. Its high pullout values might be used in suspending equipment from ceilings to save floor space. Its quality of being shock and vibration proof would be advantageous in securing heavy machinery.

3. Conclusions

During the 1978 Annual Meeting of the Minnesota Section, American Institute of Mining Engineers, J. Holmes of the University of Minnesota determined that resin-grouted bolts are more effective than mechanically anchored rock bolts. However, he cited several safety precautions which should be taken to insure their dependability. Among his comments, he stated that holes must be drilled to the proper depth to assure full bonding, and that care should be taken to store and install the bolts within the range of temperatures specified by the manufacturer.

Despite these potential problems, the chemical anchoring system possesses many characteristics which are often needed in various engineering applications. Its effectiveness in remedial work was evidenced in the economical repair work performed on Buildings 7 and 8 at the National Naval Medical Center, but perhaps the system's broadest and most valuable applications are in the area of retrofitting existing structures. It seems clear that given more examination, experimentation, and exposure to the engineering community, the chemical anchoring system will provide sound and economical solutions to many future engineering challenges.

CASE S4 - Distress in Floor, M. Yachnis

Problem: Distress on the floor of Bancroft Hall, at the U.S. Naval. Academy, Annapolis, Maryland.

Symptoms: Excessive vibration of floor due to live loading.

Collection of Facts: A/E performed a structural engineering investigation and concluded that the floor was adequate to carry only 3 P.S.F. live load. By observing the midshipmen marching in formation on the floor, it was obvious that the floor was adequate to carry more than 3 P.S.F. live load. A test was performed in accordance with ACI code requirements and the floor was found to be adequate for 180 P.S.F.

Solution: When the results of computations are disputed, perform a test with adequate instrumentation.

CASE S5 - Construction & Test of Pressure Vessels, J. V. Tyrrell

Problem: Safety of Pressure Test of Vessels with Defects.

Background: The Naval Air Propulsion Center, W. Trenton, N.J. has a number of test cells for turbo prop and jet engines. Three of these for jet engines have the ability to simulate operating conditions at altitude. While these facilities are not the largest of their kind, they are still (in 1985) some of the most sophisticated. Intake air is fed into the system severing all cells by a bank of very large blowers in a parallel configuration.

The air passes through heaters or refrigeration units into one of the test chambers containing the engine to be tested. Each test chamber is served by an exhaust gas cooler. The engine drives the exhaust and augmentation air thru the system but it is also drawn out of the gas coolers by a bank of exhaust blowers similar to but smaller than the intake blowers. The system is not only subject to high and low temperatures but operating pressures may vary from 60 psig to minus 15 psig.

Problem: S5a - Welding repair/stress relief.

Symptoms: Excessive deformation, jammed doors.

Collection of Facts: The newest of the altitude test chambers is a cylinder with its longitudinal axis horizontal and with truncated cones at each end as transitions to the intake and exhaust (see Fig. 1). The chamber may be subjected to temperatures ranging from 400 degrees F to minus 70 degrees F, and pressures from 60 to minus 15 psig. Jet engines are moved in and out through a large clam shell type door. The basic cylinder and the door are both reinforced by series of circumferential stiffeners.

Radiographic inspection of the welds joining the stiffeners to the shell revealed that over 90% were defective. Consequently a large amount of the welding was repaired. Because of the temperature and pressure conditions and the triaxial stress at the junction of the shell and stiffeners, stress relief of repaired welds was recommended. The contractor then attempted to accomplish this by heating the whole chamber. The chamber was supported on two concrete piers. As the temperature rose, the chamber sagged under its own weight.

Solution: In the case in question, it was feasible to repair or replace the damaged chamber. Fortunately, the distortion was not significant for the air flow. The door was modified to permit proper closure, and supports for the internal working platform were adjusted.

Stress relief (particularly in the field) must be carefully considered and planned or it may do more harm than good.

Problem: S5b - Pressure testing.

Collection of Facts: The altitude chamber described above is about 40' long. It was fabricated of a nickel steel (ASTM 203 Gr D with a minimum tensile yield strength of 37,000 psi) which has good ductility. However, there were many penetrations and interfaces with other materials. The inlet duct adjoining the chamber was ASTM A 201 steel and the exhaust duct ASTM A 242. Because of the welding history and general configuration, there was concern about the safety of the specified pneumatic test, which was to be conducted at 125% of the maximum positive pressure, in accord with Section VIII of the ASME Pressure Vessel Code. The test included the inlet and test sections, with the adjacent sections segregated by temporary bulkheads and separately tested.

There was even greater concern for the safety of the pneumatic teat for the exhaust gas cooler which was also a horizontal cylinder, 23' I.D. by about 50' in length, with conical ends. The cooler had six large cylindrical water tanks and two smaller headers that were set into the main shell (see Fig. 2). The configuration introduced points of triaxial stress which limits ductility. Operating temperatures in the cooler ranged from 3500 degrees F to minus 70 degrees F, and pressures from 60 to minus 15 psig.

The gas cooler was fabricated from a steel frequently used for boilers, ASTM A 212. The structure also included parts of T1 steel and a variety of other steels. The basic material was selected for resistance to high temperatures and had poor characteristics with respect to ductility. The nil ductility temperature was found by test to be about 42 degrees F. Construction proceeded into winter and a large brittle type crack appeared. The crack was repaired by welding. The cooler was scheduled for a pneumatic test similar to that required for the altitude chamber. Some welding repair had also been required on the cooler particularly at the junction of T1 steel and the shell plate.

A hydrostatic test was considered instead of the specified pneumatic test, however, investigation showed that the weight of water would significantly affect the stress distribution in the vessels. Nevertheless, a pressure test was felt to be essential in view of the design and construction history.

Solution: NAVFAC devised a test strategy of using lightweight filler material to reduce the weight of water and a A&E expert (Jackson & Moreland) was obtained for testing and inspection. The A&E developed the details and prepared a test plan. Empty spaces in the vessels were filled with glass foam insulation material which was checked for resistance to hydrostatic pressure. As a further precaution, the glass foam was sealed in polyethylene bags and lashed in place in the vessels. Water was removed from the cooler tanks and tubes for the test.

The A&E recommended that the ambient temperatures be no less than 70 degrees during the test. This was no problem for the altitude chamber which was inside a building but the gas cooler was supported by a bare steel frame. To conduct the test, the frame was draped with reinforced polyethylene plastic sheeting and portable heaters used. The water used for the test was heated.

The total weight of filler material was insignificant. A hydrostatic test was then successfully performed separately on the altitude chamber and the cooler. Testing went smoothly except that initially the inflated rubber gasket that sealed the altitude chamber door was pushed out, dumping several hundred gallons of warm water. This was caused by insufficient attention to detail. The pressure in the gasket was twice the test pressure that the vessel was to be subjected to and it was assumed that the gasket would stay in place. Actually, the internal pressure was more than enough to overcome the wet frictional resistance of the pressurized gasket. When the gasket was reinstalled, it was supported by a retainer placed for the test, and no further difficulties were encountered.

Pneumatic testing also would have been feasible because the stored energy was greatly reduced by the volume occupied by the glass foam, but the hydro test was considered safest. The glass foam was virtually undisturbed and the contractor was able to sell it back to the supplier.

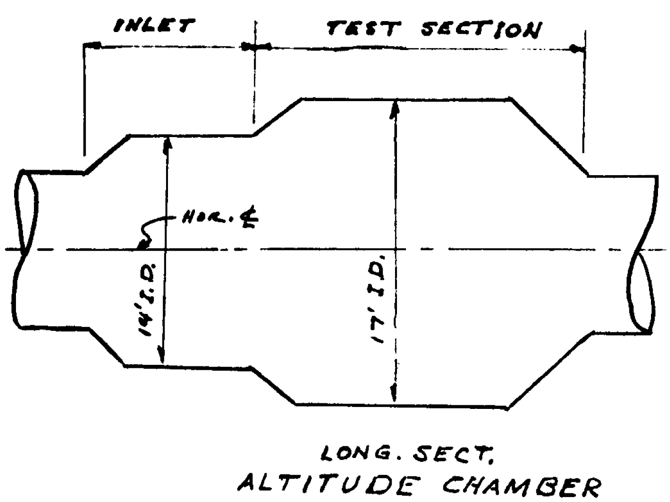


Fig. 1

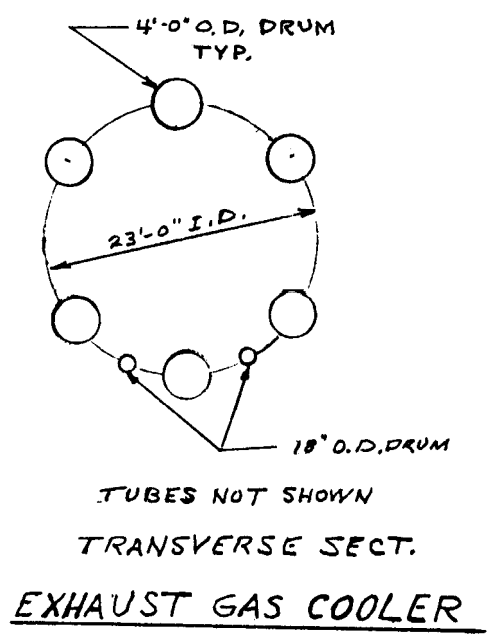


Fig. 2

CASE S6 - Seismic Codes, J. V. Tyrrell

Problem: Unacceptable Seismic Design

Symptoms: Distress in structures; requests for criteria waivers

Collection of Facts: One of the most common mistakes, made in connection with earthquake design, is the assumption that a structure which can resist code lateral forces is OK, even though it does not meet the detailed requirements of the code. These requirements are put in the code on the basis of experience. Many are necessary to insure ductility. The philosophy of seismic codes has been to use lateral forces which are considerably less than the maximum forces that would be associated with the largest earthquake motions expected to be seen at the site. It is expected that structures so designed will be undamaged by a moderate earthquake and will not collapse under the maximum earthquake.

Solution: The detailed provisions of the code are necessary to provide the ductility to meet performance expectations. Do not attempt to use portions of a design code selectively. Good details and adequate connections are as important to earthquake performance as the forces applied as design loads.

CASE S7 - Seismic Soft Story J. V. Tyrrell

Problem: Earthquake damage.

Symptoms: Damage to columns; discontinuous shear walls; failures.

Collection of Facts: In the late 1950's and 60's, a seismic design concept was introduced which utilized shear walls except for one story, usually the first floor, where a moment resisting frame was used. The idea was to absorb energy by inelastic deformations at this story. In practice, a number of serious failures have resulted, such as the Olive View hospital which was damaged in the 1971 San Fernando quake. In other cases, the same sort of problem has sometimes occurred unintentionally where discontinuities in shear walls have been used to accommodate architectural purposes.

Solution: It is evident that it is highly desirable to carry shear walls down to the foundation level.

CASE S8 - Safe Design for Blast Loading, J. V. Tyrrell

Problem: Structures just beyond explosives safety distances

Symptom: Unexpected damage.

Collection of Facts: Usually no consideration of blast loading is given to structures located outside the explosive safety arc for inhabited buildings. Although there is seldom significant damage outside of this arc, it is possible that the blast environment could be important for certain structures. Failure to consider this loading could result in damage ranging from broken glass to serious structural effects.

Solution: For important structures which are to be sited just outside the explosive safety arc for inhabited buildings, it is worthwhile to consider the blast environment that the structure may see.

CASE S9 - Structural Adequacy, J. V. Tyrrell

Problem: Structures not designed by engineers.

Symptom: Structural failures/unsatisfactory performance.

Collection of Facts: A large dead-end structure was designed for an electrical distribution line terminating at a transformer substation. Because the drawings were prepared by a well known manufacturer of electrical equipment, it was assumed that the structural design was adequate. It turned out that the structure was inadequate for the loading imposed.

Solution: Whenever a structure is a part of a manufacturer's package, require that the design drawings bear the seal of a professional engineer.

CASE S10 - Precast Concrete Arch/ Structural Details, J. V. Tyrrell

Problem: Inattention to structural details

Symptoms: Structural failures

Collection of Facts: A large precast concrete arch with a steel tie rod was designed to be supported by concrete piers. The arch was cast in two segments to be connected at the crown during erection. The piers were designed as cantilever members with spread footings proportioned to take lateral thrust on the piers during erection, before the tie was connected. Although the soil bearing capacity was adequate, no consideration was given to the effect that a small settlement might have on the position of the arch seats.

The tie was designed as a tension member and a rod of minimum size was selected. The rod was strong enough to resist the maximum load but again no consideration was given the effect of elastic stretch on the piers. The contractor devised an erection scheme that called for several arches to be erected before the first tie rod was placed. This work was performed without shoring, and the process was observed by the A&E when about three arches were in place without the tie. The ROICC mentioned that the piers appeared to have moved outward slightly and a check showed a movement a little over one inch. The A&E said that this was not a problem but should be watched.

The next day, a failure during erection caused injury to the construction crew and extensive structural damage. The primary cause was determined to be the failure to immediately connect the tie rods or alternatively provide adequate shoring. The structural calculations were then reviewed and it was found that even with erection completed and the tie in place, the stability was only marginal.

Solution: There are no complete solutions to these problems. Designers must try to think about the function of the entire system and not just crank out design for the major factors such as shear and moment. The designer should try to foresee potential problems in erection. When erection is complicated, unusual, or involves major structures, the contractor should submit an erection plan which is structurally checked. As you can see, not paying attention to details continues to be a principal cause of structural failures.

CASE S11 - Bolt Failures, E. L. Mifflin & J. J. Cecilio

Problem: S11a - Failure of ASTM A-325 bolts. ASTM A-325 bolts hot dipped galvanized can produce cracks or cracks can be produced at a later time when they are exposed to a marine environment, if their hardness exceeds Rockwell "C-32". Stress corrosion or other brittle type failure is likely.

Symptoms: Cracks can develop in the annular space around the bolts and in the roots of the threads; consequently, heads of bolts may fall off.

Collection of Facts: Hot dipped galvanizing can release atomic hydrogen (H) which permeates the ASTM A-325 bolts. This can result in hydrogen induced cracking. This has been experienced in several situations including stitch bolts for a 1500 foot guyed tower where the heads fell creating a hazard to persons on the ground.

Solution: Do not dip galvanized ASTM A-325 bolts if their hardness exceeds Rockwell "C-32”. If galvanizing is necessary, hardness should not exceed C-32, For stitch bolts, A-307 should be adequate and less costly than A-325.

CASE S11 - Continued

Problem: S11b - Failure of ASTM A-490 bolts. ASTM A-490 bolts hot dipped galvanized can produce cracks and fail.

Symptoms: Cracks can develop in the annular space around the bolts and in the roots of the threads.

Collection of Facts: The problem of galvanized A-490 bolts is similar to that experienced with A-325 bolts. Hot dipped galvanizing can release atomic hydrogen (H) which permeates the ASTM A-490 bolts. This can result in hydrogen induced cracking.

Solution: ASTM A-490 bolts should never be galvanized.

Problem: S11c - Failure of non-galvanized ASTM A325 and ASTM A490 bolts. If non-galvanized ASTM A325 and ASTM A490 bolts are attached to galvanized plates, the non-galvanized bolts may develop cracks and fail, if their hardness exceeds Rockwell "RC-32".

Symptoms: Cracks can develop in the annular space of the bolts.

Collection of Facts: Bolts that are nut galvanized, if put into contact with metal which is galvanized, may develop cracks. ASTM A325 or ASTM A490 bolts with a hardness of RC-32 or greater are subject to this problem, and potential failure.

Solution. Do not place ASTM A325 or ASTM A490 bolts, which have a hardness equal or in excess of Rockwell C-32, in contact with a galvanized surface.

CASE 512 - Sheet Piling, J.J. Cecilio

Problem: Inadequate dimensional control of welded and extruded "Y's".

Symptom: Cracks/tears/failures.

Collection of Facts: ASTM A328 "Steel Sheetpiling" and A690 "High Strength Low-Alloy Steel Piles and Sheetpiling" for use in marine environments depend on specification A-6 for dimensions control and markings. The markings in 12.3 is quite adequate; however, the dimensional control is inadequate related to the interlock dimension variation. This is especially true of riveted, welded and extruded "Y's".

Solution: The specification for the specific application should specify not only interlock strength, but also specific interlock dimensions with limited variations. It is noted here that the dimensions vary up and down the length of the sheetpiles and "Y's", especially the extruded ones. The weakest point on these piles from available data appears to be at approximately 75% of the length from the lead of hook-end as they pass through the dies or rolls. Hence dimensional variation is important.

Additional data is available from the NAVFAC library in NRL Memorandum Report 3869 "Trident Cofferdam Analysis" by C. D. Beachem dated January 2, 1979.

CASE S13 - Excessive Welding for a Guyed Tower, E. L. Mifflin

Problem: Unnecessary cost of welds for vertical member splices.

Symptom: In one case, approximately 70% of the welded fabrication of a tower was in the flange plates used to splice the vertical members.

Collection of Facts: Usually the vertical members and legs of a guyed tower are solid round bars. The legs are compression members that must be very accurately finished on the ends for true alignment in the field. The only time the member is in tension is in the erection of the mast or when it is in a cantilevered top. Many of the splice designs use a donut shaped plate continuously welded to the solid round bar to connect one leg to another. The main compressive force is transmitted through bearing of solid round ends. These donut shaped plates tend to be very thick.

In one specific design, the plates were three (3) to four (4) inches thick. The designer called for full penetration continuous welds. This was excessive and amounted to seventy (70) percent of the shop welding of the tower. This excessive amount of welding, coupled with the complex welding procedures for the material used in design (90,000 psi yield heat treated alloy steel), resulted in a very expensive structure. Continuous welding was required for a fatigue resistant design, but full penetration welds were not needed.

Solution: This is a special case where it would have paid to economize on a connection by careful design that would have considered or even specified erection procedures and actual stress requirements. Of course, it is necessary to consider the nature of the connection, the type of material, and the service conditions in designing the weld. In the case cited, the design was adequate but involved unnecessary expense.

CASE S14 - Ceramic Insulators for Tower Base, E. L. Mifflin

Problem: High cost of ceramic insulators for guys in tall guyed towers.

Symptom: Excessive bids.

Collection of Facts: Studies of the cost of "fail safe" guy insulators for 600 foot low frequency radiators showed 40 percent of material cost went for "failsafe" insulators. These insulators represented a significant part of the total cost. The cost was reduced by switching to non-fail safe insulators for the top radial systems where additional safety was not needed. The last two Omega towers designed by the government showed that using a 200 foot higher (1400 feet) grounded tower was less expensive because base and guy insulators could be eliminated.

Solution: Design VLF/LF antenna systems around available insulators when possible and consider alternatives to base insulated towers.

CASE S15 - Glass-Reinforced Plastic Guy Insulators, E. Mifflin

Problem: Use of lightweight glass reinforced plastic guy insulators as tension members. (In high voltage antennas).

Symptom: Failures in insulation due to tracking, electrical internal puncture, burning and explosive type disintegration.

Collection of Facts: In most cases of use of this type of insulators in high voltage application, one or more of the above symptoms occurred rendering the insulator useless. Only one type of insulator has passed a radio frequency high voltage test and has a five (5) year in-service record. This successful insulator is a fiberglass core reinforced cycloaliphatic epoxy cast product manufactured by TDL, Transmission Developments Limited, of Gloucester, England.

Solution: Use only TDL manufactured plastic insulators in high voltage guy insulator application, or, thoroughly test other candidates mechanically and in an RF environment.

CASE s16 - Spherical Bearing for Guyed Towers, E. Mifflin

Problem: Spherical bearing for base of tall guyed towers.

Symptom: Investigations into a cracked base insulator revealed that the difference in radii of the spherical seat was not sufficient for required rotation.

Collection of Facts: Although the difference in radii in the bearing was insufficient, the strength of the insulator was sufficient enough for the resulting bending moment. However, the replacement insulator available at that time was not sufficient for the extra bending. A new spherical seat was designed using high strength steel and special surface preparation to insure the required rotation under loading. The cost for this bearing was approximately $40,000.

After the contract for the new metal bearing had been initiated, another bearing was investigated. This bearing is a rubber pad in a "pot" used under bridge girders. The specific bearing investigated was manufactured by the Andre Rubber Company Limited, and the bearing was called "Andre Rota Bridge Bearing". An estimated cost at that time for a bearing equivalent to the steel bearing used under the tower would have been approximately $4000. As a result of these possible big savings, some research work was done at NCEL to check the claims of the bearing manufacturer. Results were promising.

Two recent towers, one a new 600 foot radiator design and the other an existing 1200 foot radiator have had rubber "pot" bearings placed under them. Before installing these bearings, a test under high voltage radio frequency was made at the Navy-Air Force test facility at Forestport, NY. The bearing performed satisfactorily. The particular bearings used were manufactured by Spencer Dynamics Corporation of Providence, Rhode Island. The antennas have been in operation, one for about a year and a half and the other for over six months. Both appear to be operating okay.

Solution: The "pot bearing" is the choice over a spherical metal bearing for the base of a "hinged" base, guyed tower.

CASE S17 - Drydock Analysis, A. Wu

Problem: In the U. S., there are over 50 graving drydocks which need to be certified at a certain point in time. Naval shipyards are usually located in areas with unfavorable soil conditions. There have been many hydraulic fills which utilize uniform, fine sands which are subject to liquefaction. These drydocks were mostly built during the past 20 to 50 years.

Loose, uniform, fine grained sands are subject to liquefaction when exposed to earthquake motions. Because of the upgraded seismic criteria, there is concern about drydock failures resulting from soil liquefaction. In the event of liquefaction, the drydock may float and/or tilt. Liquefaction also combined with high seismic inertia force may overstress or overturn the drydock wall. All of these possibilities of failure are not acceptable to the Navy.

The drydocks need an adequate structural analysis. One obvious reason is the safety requirements. A graving drydock is a stationary drydock which is built below the ground surface. The drydock is used to maintain or repair the Navy ships which include nuclear powered aircraft carriers or submarines. The seismic criteria also has been upgraded recently and a higher seismic load is considered in the analysis. Absolute safety of the ship while in dock is necessary.

Symptoms: Analysis indicating structural distress may occur under large earthquake loads.

Collection of Facts:

The drydock can be classified according to the hydrostatic pressure conditions when the dock is dry. These are: (1) full hydrostatic, meaning that the hydrostatic pressure is acting both to the floor and to the wall; (2) fully relieved type, meaning that no hydrostatic pressure to the floor and wall; and (3) partially relieved type which has only hydrostatic uplift pressure acting to the floor.

The types of loading include ship weight, static pressures, and seismic force. The soil-structure interaction, such as wall friction and subgrade response, are also included in the loading conditions.

To analyze the effects of loading, we use some loading combination as shown in Fig. 1. They may include ship load, different earthquake magnitudes, and lateral restraint provided by the crane rail tie beams which connect to the top of the drydock wall. In most cases, we use six (6) combination cases in the analysis.

Solution: An advanced and complete structural analysis using the finite element method was therefore implemented by the Navy. The analysis began with the establishment of the structural and geotechnical parameters. Once the structural configuration is set up by the structural engineer, the geotechnical engineer develops the static loads, earthquake loads, soil-structure interaction, and the possible lateral restraint provided by the adjacent structures.

In most of the cases, the concrete tie beams which connect to the drydock wall must be included in the analysis because of the lateral restraint to the wall displacement and the added rigidity to the drydock wall. See Fig. 2.

The numerical analysis is performed by the NASTRAN computer programs, which are widely used in the Naval Ship Research and Development Center, in Washington, D. C. The first step of the analysis is to formulate the finite element mesh which is most suitable to the analysis. About six finite element models, meaning six (6) loading cases, are generally selected for the analysis. Some of the results are shown by Figs. 3 through 6. Fig. 3 shows the formulation of a finite element mesh, Fig. 4 shows a displacement pattern of the drydock subjected to a loading case, Figs. 5 and 6 show stress profiles of the floor slab.

From the experience of drydock structural analyses, we have learned that: (1) we cannot use the elementary strength of material concepts (i.e. $f=My/I$ equation); (2) we cannot use the equilibrium of free body concepts; (3) we can use two dimensional finite element method, considering linear or non-linear material properties; and (4) we may use Navy's earthquake loading criteria and computation. The method of computations are described in the Navy's design manuals DM-7.2 and DM-7.3. The Navy's DM-7.3 discusses the factors affecting liquefaction and the empirical method of liquefaction potential evaluation.

The soil liquefaction problem during earthquake is still a great uncertain field. Many difficulties arise when assessing the liquefaction potential. Some methods have been used, but the methods are still incomplete or questionable. To evaluate liquefaction potential quickly, a simple flow chart is developed to check the problem, as shown on Fig. 7. The flow chart gives an idea whether a more sophisticated evaluation is warranted.

Conclusion:

In conclusion, it was found that: (1) we can use geotechnical mechanics principles to model the soil-structure interaction; (2) we cannot use over-simplified structural mechanics principles to solve the stress-strain interaction of the structure; (3) we must be careful in considering the boundary restraint, (4) it needs adequate models to compare the results to assure the accuracy of the analysis; and (5) the last but not the least, that the analytical results must be checked by experienced structural and geotechnical engineers. This is to assure that the results are dependable and correct.

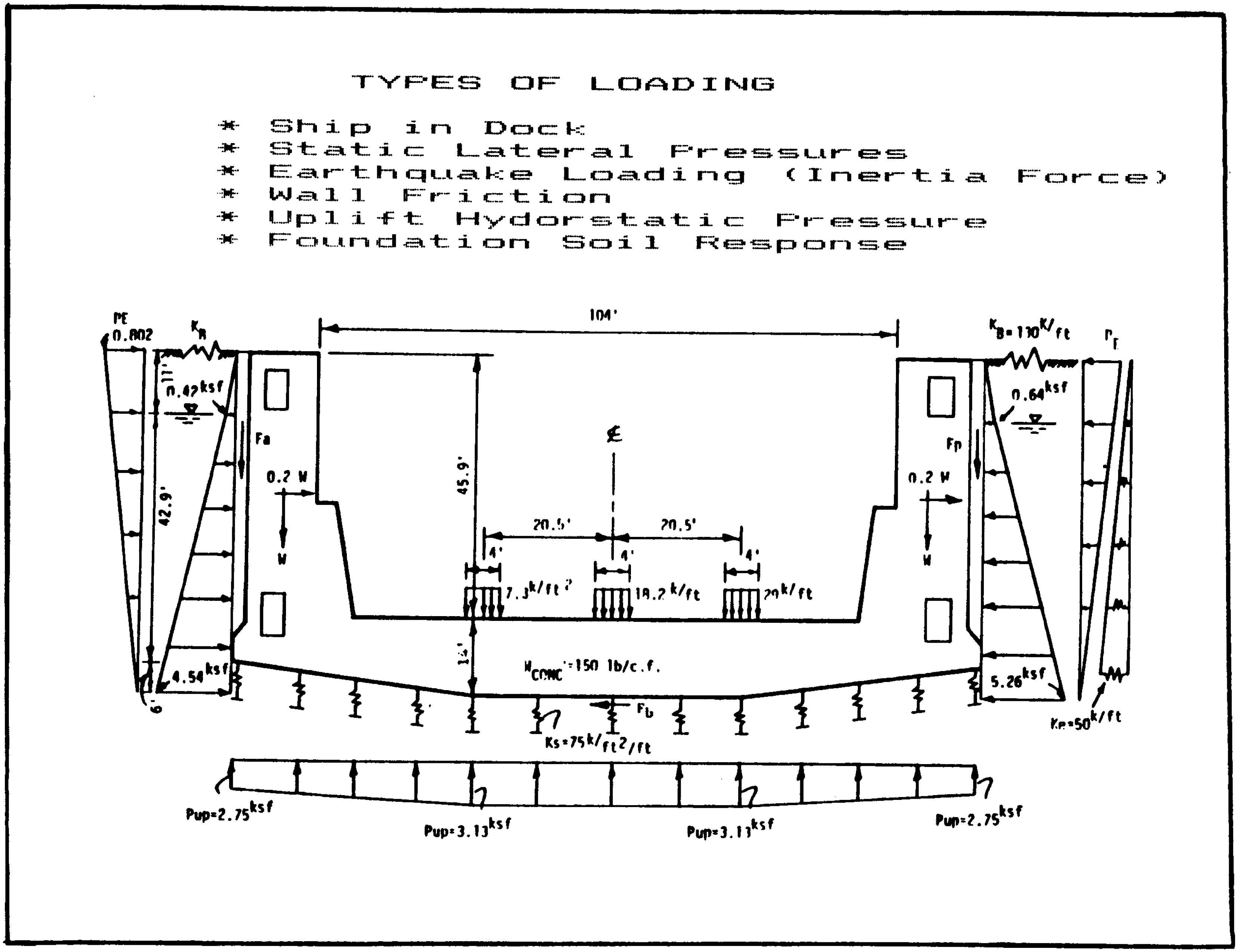


Fig. 1. Drydock Loading Conditions

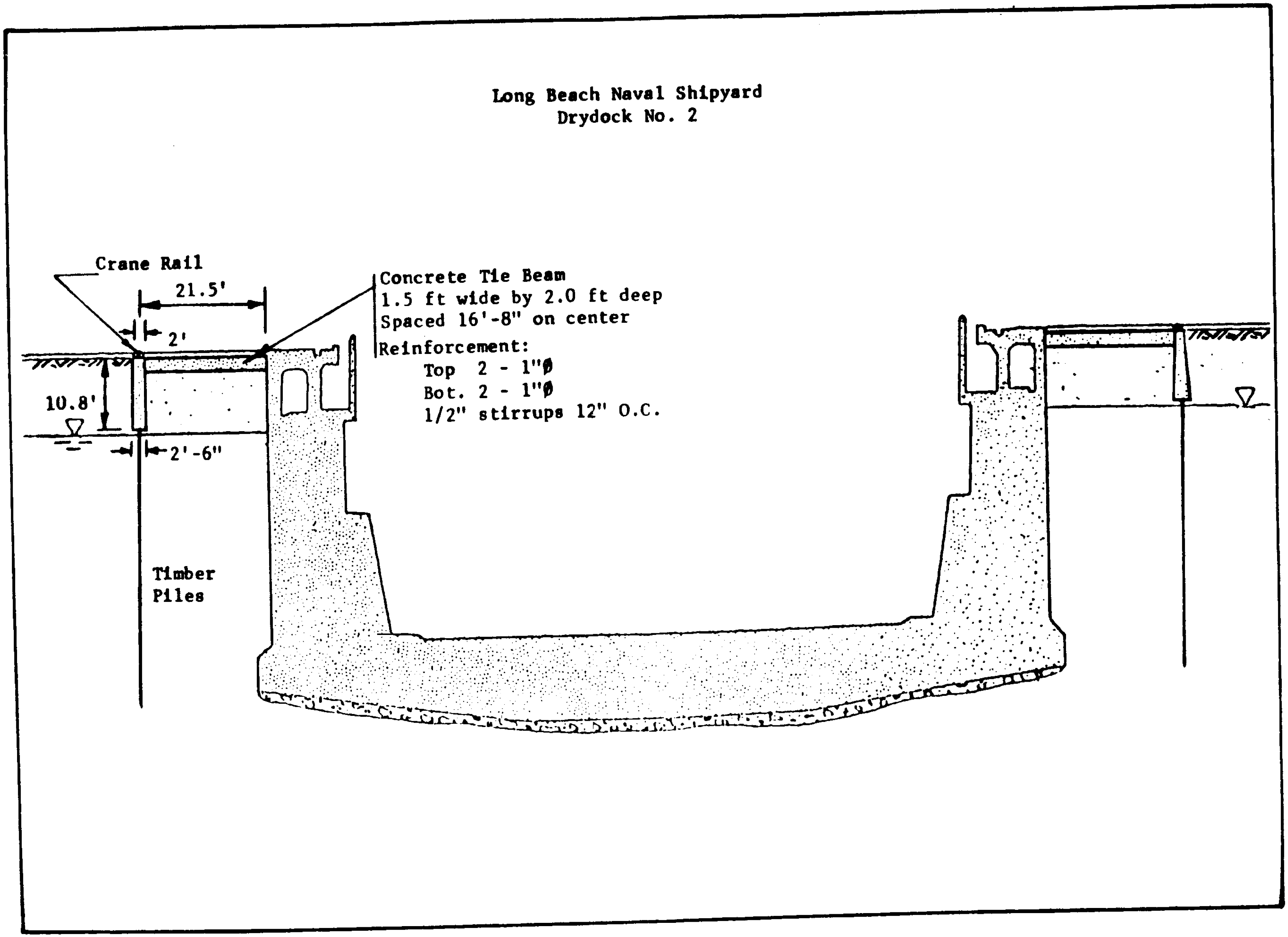


Fig. 2. Crane Rail Support and Concrete Tie Beam

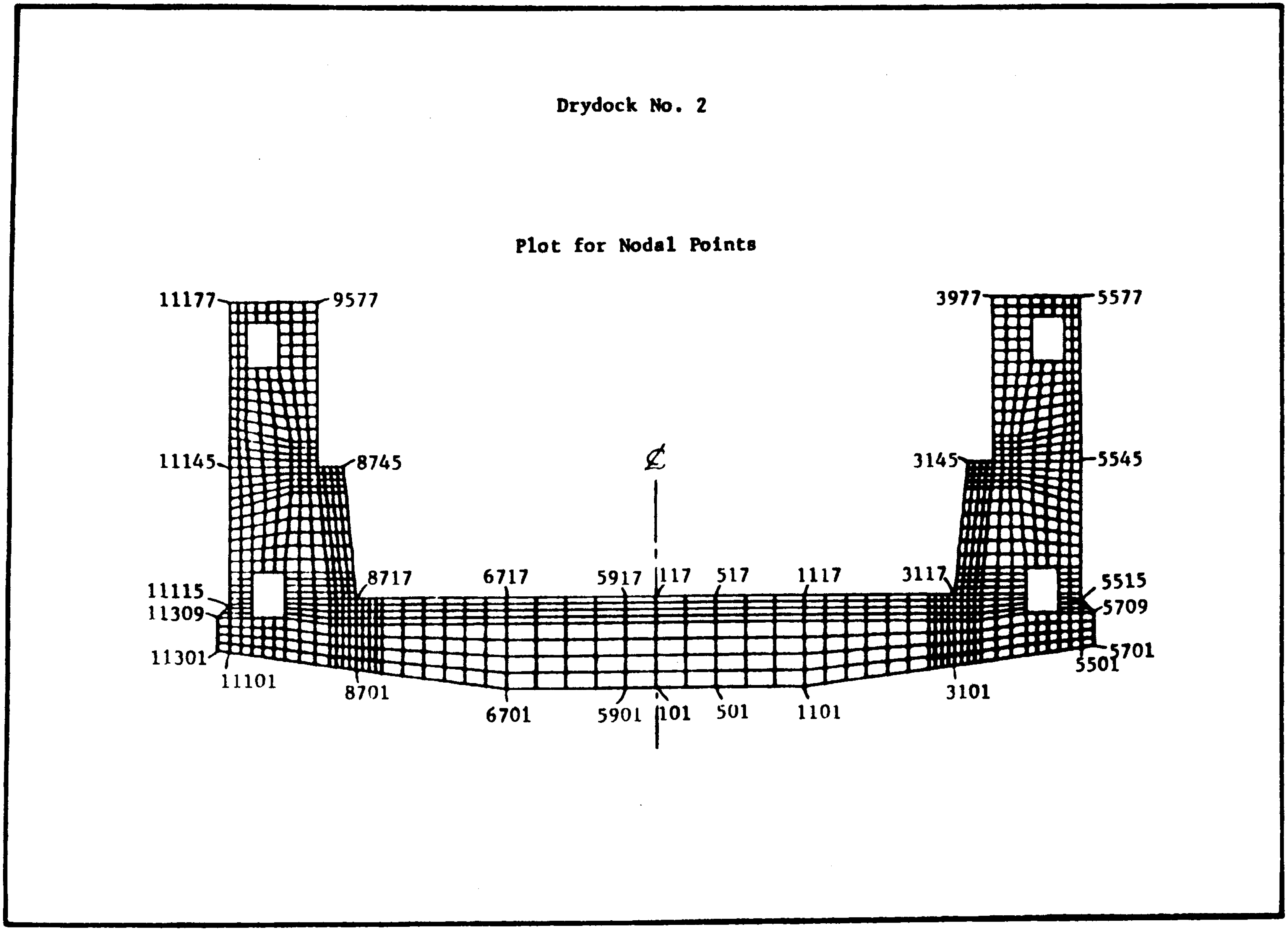


Fig. 3. **Formulation of Finite Element Mesh**

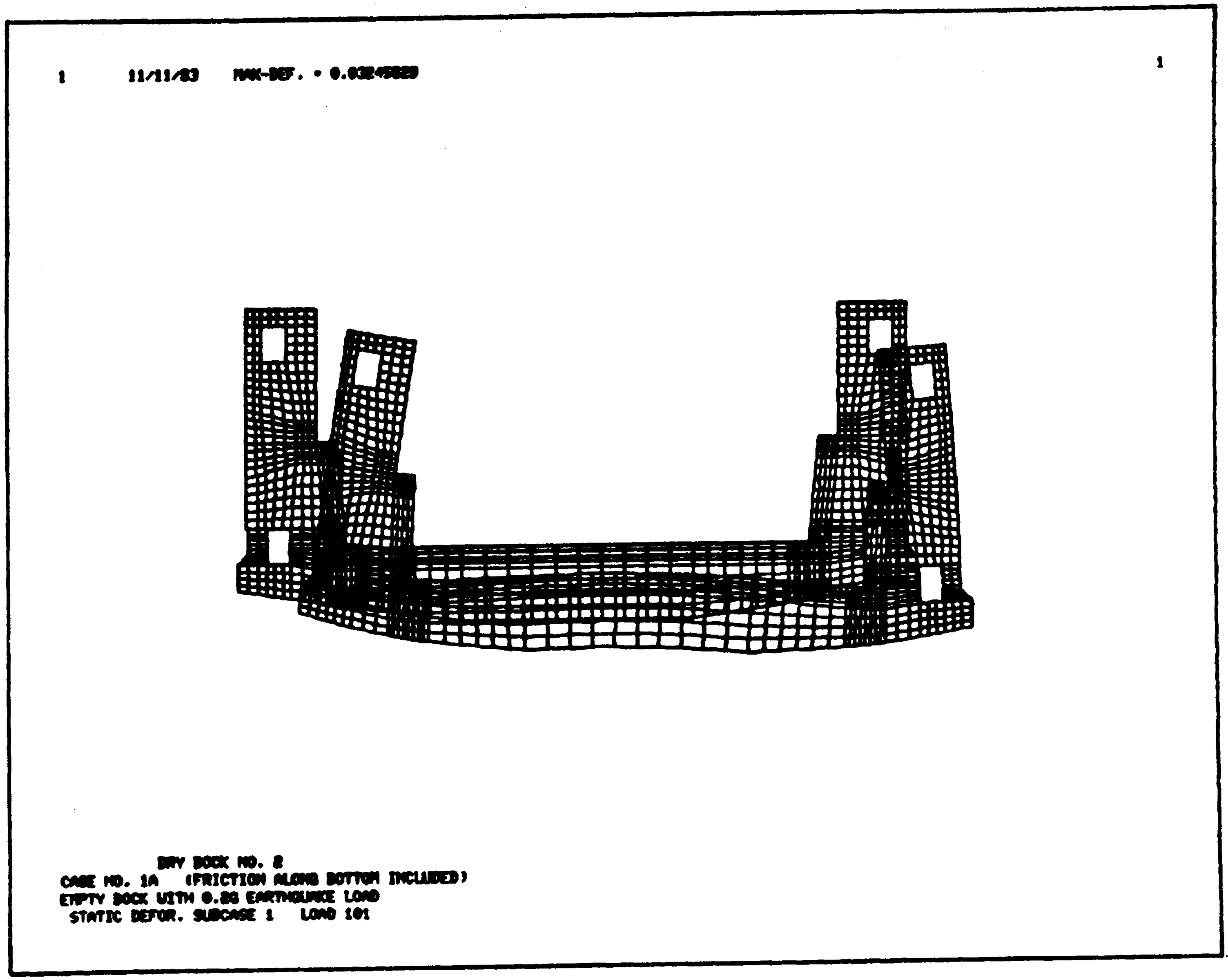


Fig. 4. An Example of Drydock Displacement Under Loading

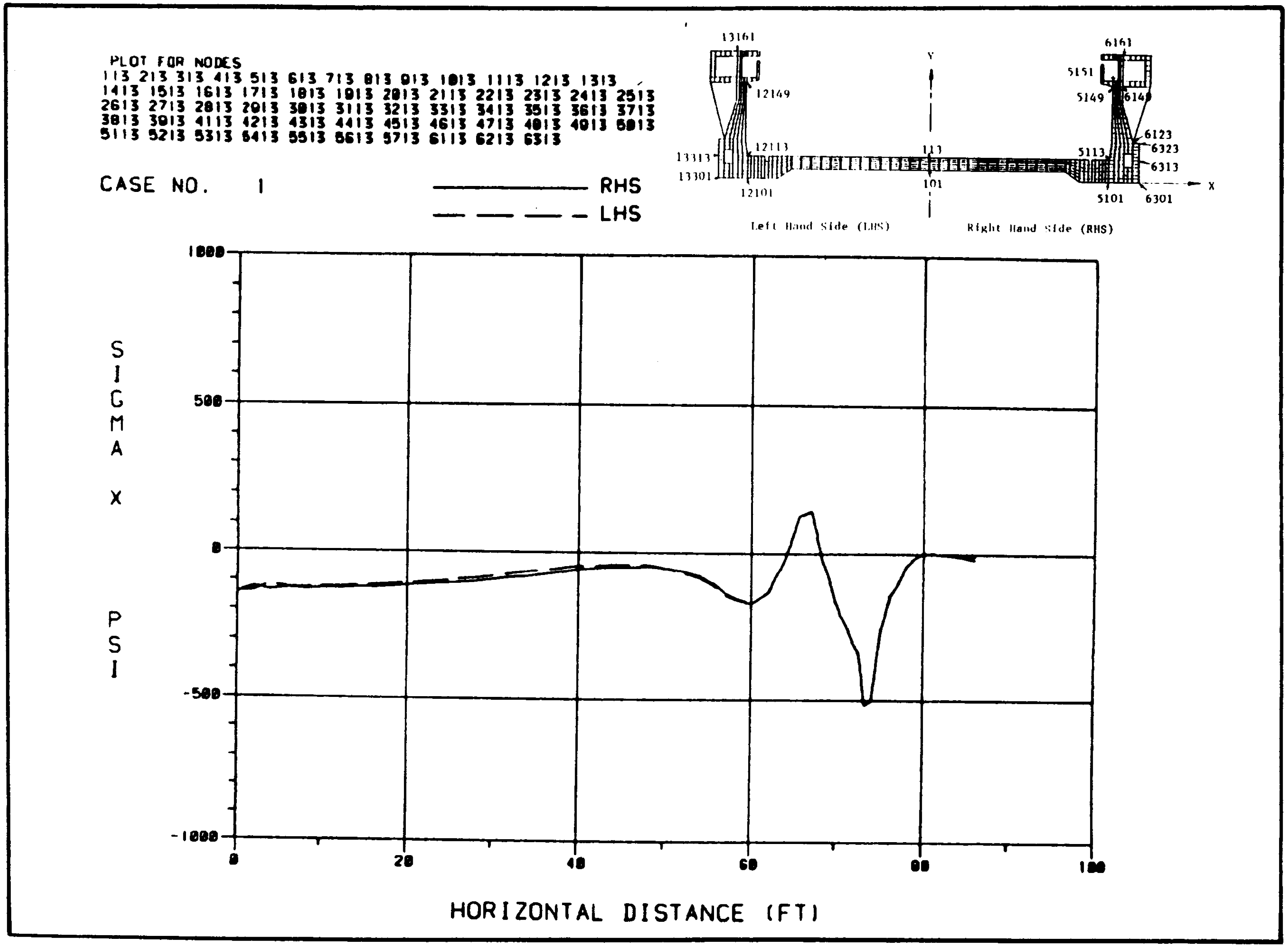


Fig. 5. Sigma-X Stresses Along the Top of the Floor Slab - Model No. 1

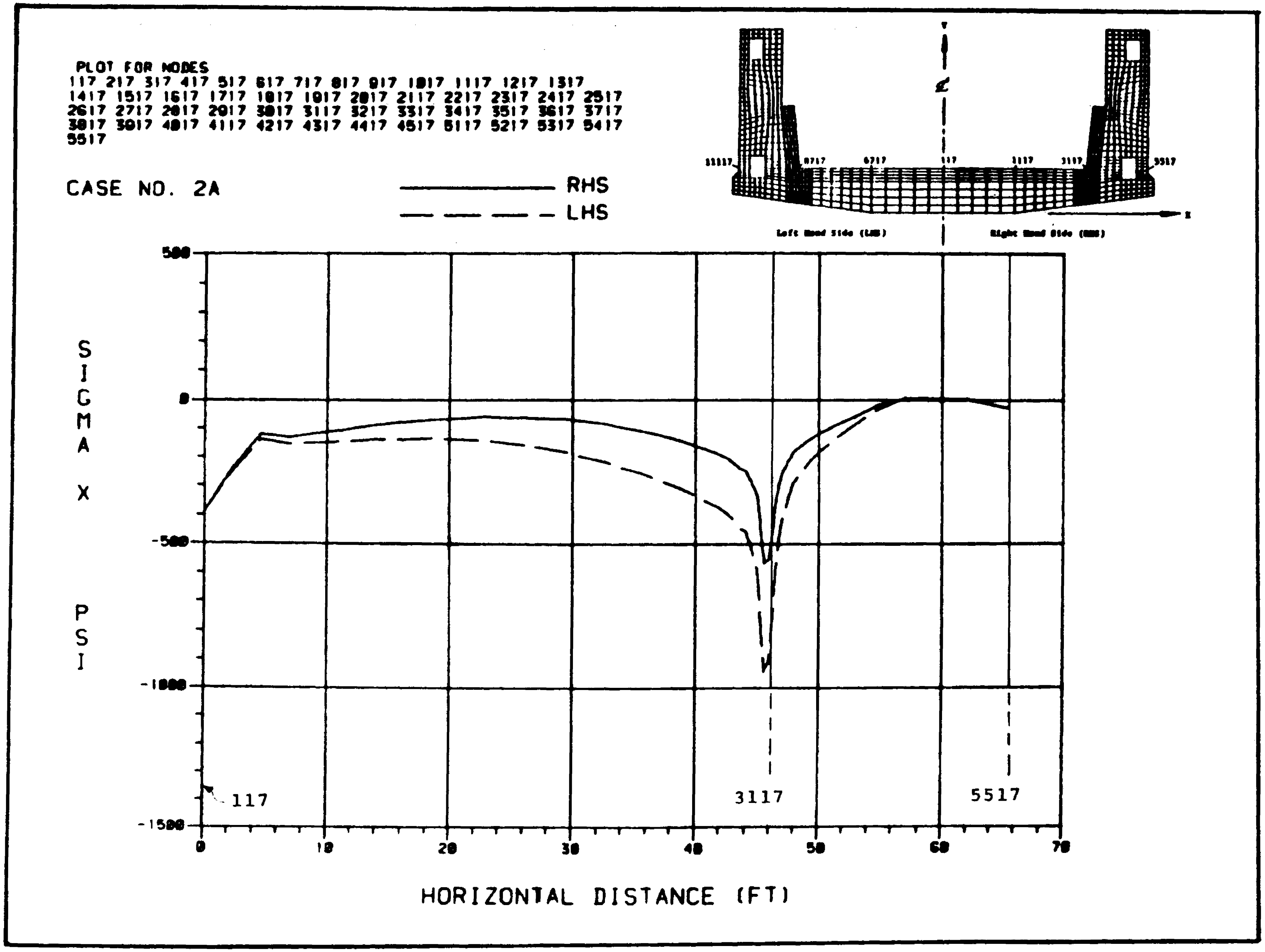


Fig. 6. Sigma-X Stresses Along the Top of the Floor Slab - FEM Model No. 2A

Steps for checking liquefaction potential

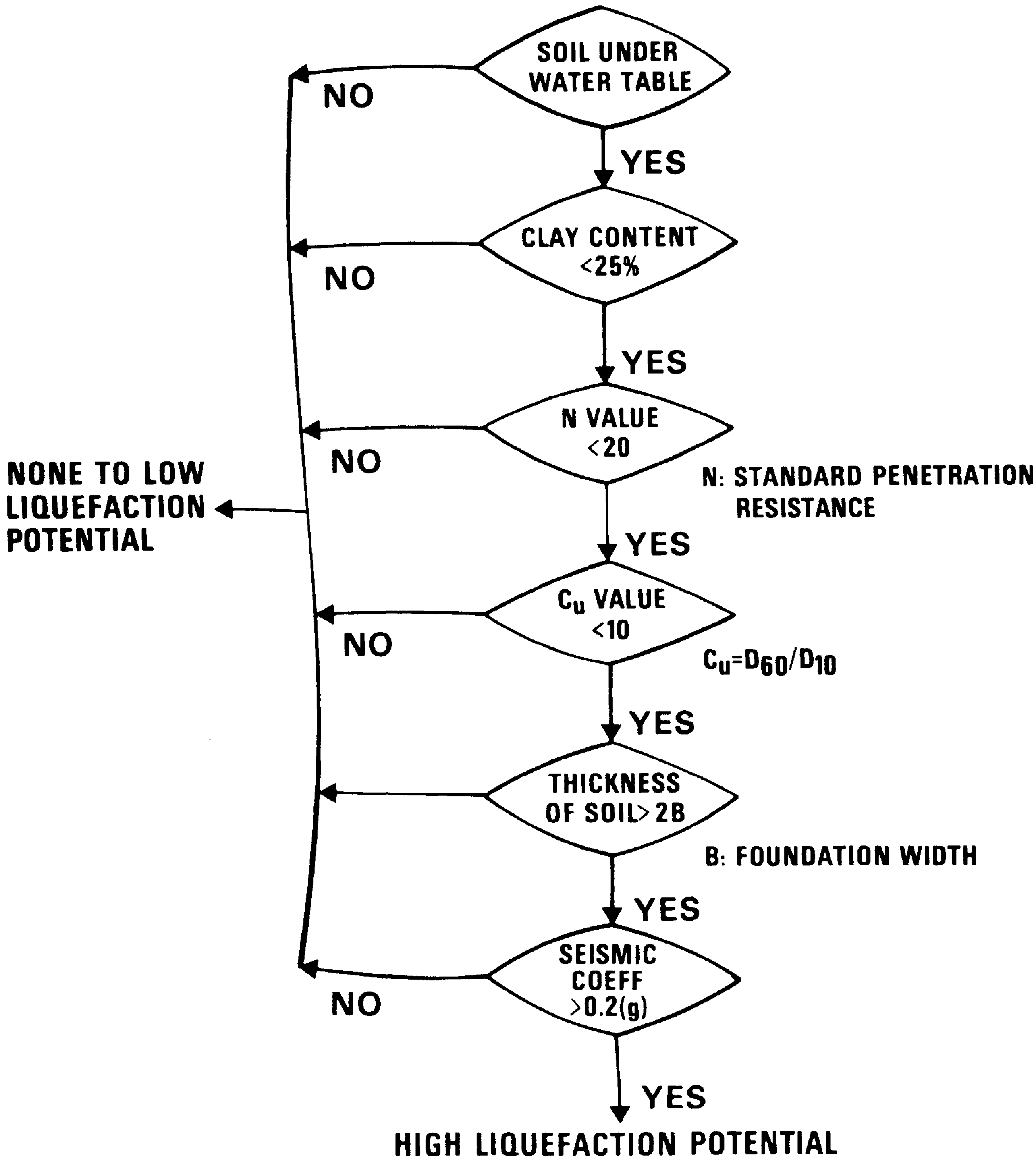


Fig. 7. Flow Chart for Checking Liquefaction Potential

CASE S18 - Concrete Repair, P. Malone

Problem: Failure of concrete patches.

Symptoms: The repairs made to concrete walls were not lasting a reasonable length of time. Poor bonding to the old surface was apparent in most cases.

Collection of Facts: A review of the procedure indicated that not all the personnel involved in the concrete repair process were aware of the importance of a clean rough surface as well as other factors in good concrete repair procedures.

Solution: The engineering staff and the maintenance staff shall train the work crews before they are sent out to undertake repair projects on concrete.

METALLURGICAL

CASE ML1 - Weathering Steel, J. J. Cecilio

Problem: Failure of weathering steel ASTM A-690, A-588 and A-242.

Symptoms: Reoccurring cycle of rusting and flaking off under failure of the section.

Collection of Facts: The copper bearing low alloy steels defined above CORRODE RAPIDLY IF NOT BOLDLY EXPOSED TO THE ELEMENTS OF SUN, RAIN AND WIND. These steels are marketed under ASTM A-690, A-588 and A-242. Their trade names are Corten, Marten and Mariner. To prevent buildup of salt or other contaminants during the wetting and drying cycle, any portions of a structure not boldly exposed to the elements must be protected by painting or by the application of a barrier.

Solution: Structural elements made of weathering steel that may build up salts and other contaminants shall be painted with a transparent varnish. Further information can be obtained from U.S. Steel Company.

ASTM-A-609 Mariner steel piling, wetting and drying portions should be blasted clean to near white metal and then coated by a 40 mil-carboglass 1601 polyester glass flake. Source is the Carboline Company.

CASE ML2 - Use of Special Materials - Antennas, E. L. Mifflin

Problem: Selection of special high strength material.

Symptom: Contractors declined to bid on project.

Collection of Facts: A design for a tall tower utilized 90,000 psi heat treated alloy steel in order to reduce the size and weight of members. The material required special welding specifications and resulted in a structure which contractors declined to bid on. There were only three well qualified potential bidders and all initially declined to bid. Two bidders flatly refused to consider undertaking the project. The third bidder finally agreed to a negotiated contract. The use of the material selected increased the cost by an estimated 2.5 million dollars and the total cost was undoubtedly increased because it was not possible to obtain competitive bids. Needless to say, the negotiated price was not favorable to the government.

Solution: Investigate all aspects of cost and availability before using special materials. Material that requires welding should be avoided for tower construction.

CASE ML3 - Galling of Sluice Gates, J. Cecilio

Problem: Galling of Sluice Gates

Collection of Facts: It was reported that the trim for the sluice gate of Drydock No. 3 at Pearl Harbor was experiencing severe galling. The new sluice gate was trimmed with monel metal. Complete elimination of galling of the seating surfaces is very difficult to achieve. A survey of Naval Shipyards was performed for evaluating galling of sluice gate which is as follows:

a. San Diego Naval Shipyard: Sluice gates, manufactured by Armco are cast iron with monel trim. Minor problems with galling.

b. Portsmouth Naval Shipyard: Sluice gates, manufactured by Rodney Hunt, are cast iron with bronze trim. The gates on one dock have no trim with cast iron seating surfaces. They have experienced no galling.

C. Long Beach Naval Shipyard: Sluice gate cast iron with bronze trim. Some minor problems with galling. They repaired the trim on the gates of one dock by spray metalizing with bronze and remachining.

d. Puget Sound Naval Shipyard: Sluice gates, manufactured by Rodney Hunt, are cast iron gates and frames trimmed with monel on one dock. They have one set of gates yard-manufactured. They have experienced minor problems where the seating surfaces were of like material.

e. Norfolk Naval Shipyard: Sluice gates are cast iron trimmed as follows: Dock #2-cast iron with CUNI trim ASTM B-122 alloy 715; Dock #4-cast iron with phosphor bronze trim built by Armco-ASTM B-139 alloy 510; Dock #8-cast iron with either monel or bronze. They have experienced no galling problem.

f. Mare Island Naval Shipyard: Sluice gates for two docks are cast iron with the exception of those for Drydock #l which are stainless steel type 304 purchased in 1958. Some galling has been experienced. One cast iron gate is trimmed with monel purchased in 1938. On this gate, some galling has been experienced. The gates purchased in 1938 are trimmed in bronze. Galling has been noted on this gate's matting surface.

g. Newport News Shipbuilding and Drydock Company: On their docks for carriers, they are using stainless steel trim. They are in the process of replacing the other gates at this time.

Solution: The following guidance was developed:

1. Like metals such as 400 monel to 400 monel may be successfully used for trim when the unit pressure from the water head is low-below 2,000 psi.

2. The normal surface finish should be 63 micro inches or better.

3. When pressure exceeds 2,000 psi, ARMCO used materials of differential hardness or dissimilar metal for the gate trim and the frame trim. As an example, for high water head cover 2,000 psi it was common for one side of the sealing surface to be made of 304 stainless steel while the other side was made of Phosphor Bronze.

FATIGUE

CASE F1 - Connections of Struts for Grading Rings - Antennas, E. Mifflin

Problem: Failure of end connections of tubular struts supporting anti-corona and grading rings.

Symptom: Connection failed.

Collection of Facts: Though the connection was eccentric, the calculated static stresses were well within acceptable limits. Since the member was tubular, approximately three (3) inches round, aeolian vibrations were suspected.

Solution: A coiled cable was inserted in one end of the tubular member. The cable was attached at that end and the end was sealed to the weather. This cable, which was slightly longer than the tube, damped any vibrations in the tube. No end connection failures have occurred since installation of the damper cable.

CASE F2 - Evebolt Failures - Antennas, E. Mifflin

Problem: Eyebolt failure in "fail safe" insulators.

Symptom: Eyebolts in compression cone "fail safe" insulators failed resulting in loss of guy support. Failures occurred in both types of connectors generally used. One type a threaded rod with ball nut failed in the threads. The other type failed at the junction of the shank and bolt head. (None failed in the eye). Bolts were in tension and bending.

Collection of Facts: Failures were initiated at cracks and/or areas of high stress concentration. First, a gradual fatigue failure developed until the cross section of the member was reduced sufficiently for a tension failure. Analysis of the bolt revealed very high bending stresses as well as the design tensile stress. The geometry of the area of failure is such that high stresses are generated at reentrant corners. The material is a heat treated forged high carbon steel. (AISI numbers 1035 and 1040). In the threaded bolts, cracks were found in the threads of some that had not failed. Improper weld repair to forged areas that were threaded also may have been a factor in initiating the fatigue crack. The Navy, Air Force and Coast Guard, as well as private industry, have many of these members in place functioning today. Replacement of them would be a very costly undertaking. In most cases, the failure of a guy would not endanger life.

Solution: In some cases, we have reduced the stresses by reducing tension in the guys and consequently the likelihood of bolt failure. For the Navy structures where failures had occurred, the eyebolts were inspected and ones with cracks were discarded. An investigation of a later failure at one site revealed that for certain guys, the tensions had not been reduced and the failure occurred at such a location. A completely new design for an eyebolt had been developed and is in use. The metallurgy has been improved greatly for this bolt. The geometry and stress level have been vastly improved also by having an upset threaded end and a special rounded thread. However, the original manufacturer has gone out of this business, and the other manufacturer has destroyed all of his casting and forging patterns.

CORROSION

CASE CR1 - Piping Corrosion, J. Cecilio

Problem: Building corrosion into your piping systems.

Symptom: High maintenance cost and early failure.

Collection of Facts: Define the purpose of the design. Define its environment.

Solution: Use basic engineering design considerations to evaluate the design for corrosion.

a. Design for easy cleaning and drainage.
b. Design for easy component replacement where service failure is anticipated.
c. Avoid high localized stress concentrations.
d. Avoid dissimilar metal contacts.
e. Minimize or exclude air.
f. Avoid heat transfer hot spots.
g. Join by welding rather than bolts or rivets.
h. Use smooth wide radius bends in piping systems.
i. Avoid metallic contact with absorptive materials.
g. Avoid high velocities.

CASE CR2 - Aluminum Corrosion in Wood, J. Cecilio

Problem: Corrosion of Aluminum in wood-aluminum assemblies.

Symptom: Corrosion of aluminum fasteners in fender pilings.

Collection of Facts: Corrosion of aluminum in wood-aluminum assemblies can be prevented by using well seasoned wood, coating aluminum with bitumen or other electrically neutral barriers and avoiding woods that produce a pH 5.0 or above 7.O as well as bi-metallic action.

Solution: If aluminum fasteners are specified use bitumen paint or other electrically neutral barrier and avoid woods that produce a pH below 5.0 or above 7.0.

CASE CR3 - Corrosion of Galvanized Guy Cables, E. Mifflin

Problem: Rapid corrosion.

Symptom: Corrosion and possible loss of strength.

Collection of Facts: Cables had a Class A galvanizing and were subject to a very hostile corrosive environment. To preserve longevity of the guys they had to be coated to resist rusting further. The cables range from one inch round to three and one eight inch round, and it is very costly to replace them.

Solution: A solution of on site conditions was to develop a coating mechanism and rigging to place a protective grease coating on the cables. For new construction, it is recommended that the designer specify a Class C galvanized coating on the outer wires of the cables. Life expectancy is three times that of Class A.

CASE CR4 - Steel Conduit, T. Hayes

Problem: Rigid steel conduit installed on self-propelled craft.

Collection of Facts: The steel corroded at an accelerated rate.

Solution: Avoid steel conduit in a marine environment. Use PVC conduit.

CASE CR5 - Improper Ventilation in Sump Areas, T. Hayes

Problem: Improper ventilation in sump area of pumphouses and pump wells causes rapid deterioration of mechanical equipment.

Collection of Facts: In the sump area of many pump wells, there is an accumulation of moisture resulting from leaking, packing from drainage pumps, water seeping though the pump well walls and numerous other sources. Because of the damp condition that exists, mechanical equipment such as pumps, valves and piping corrode at an accelerated rate. In most of these areas, ventilation is inadequate.

Solution: In the design of future pump wells, insure that adequate ventilation is provided in the sump pit area.

CASE CR6 - Galvanized Piping System for Hyperbaric Systems, R. Johnston

Problem: Problem with Galvanized Piping System.

Symptom: Internal corrosion in piping system.

Collection of Facts: In the past, some L.P. air systems for hyperbaric chambers have utilized galvanized piping while performance has been satisfactory. The use of trisodium phosphate (TSP) as a cleaning agent could potentially dissolve the zinc and leave the pipe vulnerable to corrosion.

Solution: Avoid galvanized piping on new systems. On existing systems ensure that TSP is not used to clean the system.

Case CR7 - Mariner Steel Fender Piling, J. Cecilio

Problem: Corrosion of Mariner Steel Fender Piling

Collection of Facts: The 132 H steel piles located at the Trident Wharf are eighty feet long and conform to the HP 14x102 shape. The material specified is of the ASTM A690 chemical composition and is commonly known as Mariner Steel. These pilings were driven into clay bottom approximately twenty feet, The remaining sixty feet includes forty feet in the immersed zone and the final twenty feet above water. Tidal fluctuation in the basin causes about four feet of the pile to be alternately wetted and dried twice daily. The piles have been in place since the facility was built in 1975.

Portions of the piling subject to tidal fluctuations sustained the most damage. Close observation revealed that 1arge sheets of corrosion product were easily removed exposing pitted steel underneath.

Measurements were made to calculate percent reduction in thickness of flange and corrosion rate of the H piling. The corrosion product was first chipped off and then scraped to reveal the underlying steel for obtaining accurate measurements. In addition to the uniform corrosion, many severe pits were observed with depths estimated at 50 mils (0.050") or more. The pit depth would be subtracted to determine the resulting thickness at the H piling HP 14x102 AST, A690.

Flange thickness before corrosion	0.704"
Flange thickness after corrosion	0.550"
Decrease in thickness due to pitting	0.050"
Resulting thickness at area of pit	0.500"

Percent reduction due to corrosion (at area of pit):

$$1- \frac{(0.500)}{(0.704)} \times 100 = 28.98\% = 29\%$$

Therefore, in four years of services, 29% of original material has been lost due to corrosion.

Corrosion rate (inches penetration per year):

(0.704″-0.500″)/4 = 0.051 ipy

51 mils/year (1 mil = .OOl inches)

Subsequent to thickness measurements, a detailed diver report and photographs were made. The diver inspection included observations starting at the surface and concluded at the mud line. Below water, the surface condition changed and was observed to be covered by a soft powdery corrosion product that was black in color. This film was easily removed to reveal the underlying steel which seemed in good shape. This condition persisted all the way to the mud line indicating uniform corrosion beneath the water. Although no thickness measurements were made below water, the divers indicated the piling appears to be sustaining leas damage below water than in the tidal zone.

Solution: The corrosion rate and damage to the pilings was unacceptable. Two methods were recommended to control the corrosion rate:

a. The system providing the best protection was a near white blast of the steel followed by a 40 mil coat of carboglass 1601 polyester glassflake manufactured by Carboline Company. Several other coating systems performed well, but the glassflake received the highest evaluation in the atmospheric, immersed, and sand-swept zones. The system also provided excellent abrasion resistant and would hold up to the abrasion produced by the camel mooring system used for the submarines. The problem with using this system would be the cost of removing and reinstalling the pilings. However, this would be protection recommended for any fender pile system during initial construction or installation.

b. A second method that would afford protection could be applied with pilings in place. It is a system of epoxy encasement of the steel piling in the tidal zone. A fiberglass form is placed around the piling and the epoxy mortar is poured to seal out the corrosive environment. The firm that provided this information is Logan Engineering Contracting Company in Jacksonville, Florida. Since encasement of the piling all the way to the mud line would be extremely expensive, catholic protection could be used in conjunction with this system to yield acceptable results. However, there is no documented corrosion performance data available on this encasement system.

CASE W1 - Distortions in Welded Structures, J. Cecilio

Problem: Structures such as POL tanks and radio shielded rooms require large areas to be covered by steel plates and connected by welding to insure tightness. These facilities require a great deal of planning, preparation, and care in fabrication to insure proper fit and to minimize warpage and distortion.

Collection of Facts: When improper welding methods are used excessive buckling and warpage occur requiring additional rework and increased cost.

Solution: Distortions and warpage in welded plates can be minimized and satisfactory results can be obtained, if the proper methods are used. Distortion and warpage can be minimized by adherence to the following:

a. Don't overweld.
b. Control fitup.
c. Use intermitted welds where possible.
d. Use the smallest size of weld permissible.
e. Use minimum root opening, including angle and reinforcement.
f. Select joints that require minimal weld metal, for example, a double "V" joint instead of single "V" joint.
g. Weld alternately on either side of the joint when possible with multiple pass welds.
h. Use fewer weld passes/ high deposition rate.
i. Use higher speed welding methods (iron powder coated electrodes or mechanized welding, etc.)
j. Use welding methods that give deeper penetration and thus reduce the amount of weld metal and heat needed for the same strength.
k. Use welding positioners to achieve maximum amount of downhand welding, allowing the use of larger diameter electrodes or higher deposition rate welding procedures with faster welding speeds.
l. Balance welds about the neutral axis of the member.
m. Distribute the welding heat as evenly as possible through planned welding sequence and weld position.
n. Weld toward the unrestrained part of the member.
o. Use clamps, fixtures and strongbacks to maintain fitup and alignment.
p. Prebend the members or preset the joint to let shrinkage pull them back into alignment.
q. Weld those joints that cause the most contraction first.
r. Weld the more flexible section first so they can be strengthened, if necessary, before final assembly.
s. Sequence subassemblies and final assemblies so that the welds being made continually balance each other around the section's neutral axis.

CASE W2 - Acceptance & Inspection Criteria. J. V. Tyrrell

Problem: Inspection & Acceptance Criteria

Collection of Facts: Often disputes arise over whether or not an item meets the contract requirements. This is particularly true where performance specifications are used. However, it also is a problem for contracts where explicit specifications are used. Some of the common causes are: conflicts or errors in the plans and specifications, vagueness, insufficient, definition, reliance on references to standards or codes without knowing enough about their content, failure to state essential inspection requirements (methods and timing), failure to specify how acceptance tests will be evaluated and how deficiencies are to be resolved, deviations from plans or specifications permitted by field personnel without design consultation.

One example of such a dispute involved welding of a gas cooler for a jet engine test cell. This unit was designed for both positive and negative pressure and for temperatures ranging from minus 67 degrees to 3500 degrees fahrenheit. The specification required radiographic inspection of welding in accord with Section 8 of the ASTM Pressure Vessel Code.

The referenced code, at that time, required a sampling of welding and, where defects were found, the sample was to be extended a certain distance each side of the original sample. Then all the defective areas were to be removed and rewelded. Under this code, unacceptable defects included cracks, lack of fusion, and incomplete penetration. There was no standard for porosity.

When the welds were examined, the laboratory performing the inspection recommended rejection of 95% of the sampling. Most of the welds contained all the defects listed, however, about 20% were cited principally for porosity, undercut, and other things not specifically covered in the referenced code. On the basis of these results and to avoid delay in construction, the Resident Officer in Charge of Construction ordered radiographic inspection of the welding. This resulted in repair of over 90% of the welds.

The contractor subsequently claimed that some welds were rejected that were actually not unsatisfactory according to the specification. He also claimed that if the inspection procedure specified had been followed, some welds containing defects would have been accepted. The government asserted that it had the right to extend inspection under the general provisions of the contract and that the rejected welds all failed to show acceptable workmanship. In the end a compromise settlement was reached, but the contractor got the lion’s share.

Solution: There is no sure way to avoid all the pitfalls which are inherent in design and construction. It helps to know the content of referenced material particularly for important, unusual, or complex construction. It is, of course, necessary to thoroughly check the plans and specifications and consider the possible need for a constructibility review. Also think about the things that you do not want as well as those that you intend to have in the finished product, and how a third party would evaluate the construction against the contract documents. Always make sure that the acceptance criteria is clear.

CASE C1 - Industrial Waste Treatment & Electroplating Facilities, L. Wernigg & J. Yacoub

Problem: The Navy is operating a large number of industrial waste treatment (IWT) and electroplating (EP) facilities with varying degrees of effectiveness, with several plants having difficulties meeting effluent limitations and having excessive operations and maintenance problems.

Symptom: Several IWT plants do not meet toxic heavy metal discharge requirements imposed by Federal and State regulatory authorities (Nov. 1984). Furthermore, there are serious problems with inoperative instrumentation and control systems, with excessive maintenance requirements for some of the installed equipment and other difficulties.

Collection of Facts: A review of the project histories of several IWT plants and electroplating shops and post-occupancy evaluation reports revealed that problems are not reducible to one or two major causes. They derive from a wide range of factors relating to preliminary engineering studies, the government contracting process, A/E selection, design, project funding, construction inspection, staff selection and training, changing environmental regulations, high rate of inflation of the 70's, and the very nature of industrial waste control itself.

Solution:

Background: Under the Post Occupancy Evaluation Program, four IWT and one EP facilities have been evaluated to date. These IWT facilities are located at: NWSC Crane, NAS North Island, NAS Jacksonville, and NARF Norfolk. The EP facility is at Norfolk NSY Portsmouth, VA. An additional IWT facility at MCLSBA, Albany, GA had a detailed review prior to including IWT in the POE program.

These evaluated facilities represent twelve years of project planning and acquisition efforts. During this period of time, the country progressed from dumping (to oceans, streams, lakes or land disposal sites) much of its pollution generated at industrial facilities to collection and treatment plants to meet very strict Federal and state discharge criteria. As a direct result of the Federal Laws and Executive Orders mandating this major change, a large number of projects were initiated to implement these requirements. All of this happened at a time when we were not staffed to handle the planning, design, construction and operation of these facilities. The A/E community was also unprepared.

Summary of POE Findings: Table 3 on page 44 provides an analysis of deficiency types for five post occupancy evaluations conducted in the industrial waste treatment and electroplating category. All of these IWT plants are first generation or upgraded first generation plants, therefore identifying trends would be premature. In addition, one of the POEs, at Crane, was unique, because basically it was designed, built and operated by one small private firm. Because of the operation by a private contractor, it was difficult to evaluate it on the same basis as a Navy-run facility.

The majority of the deficiencies (39%) are design deficiencies. As mentioned earlier, most of the consulting engineering firms hired to design these facilities were inexperienced in this field. Even when a second A/E (consultant) was hired to critique the design A/E's submission (NARF, Norfolk project), the majority of the deficiencies were still design related. This shows how important it is to select a highly qualified firm to design these facilities.

The next highest categories of deficiencies are related to construction (18%) and design criteria (14%). Adequate design criteria is lacking in the existing DM 5.8 Pollution Control Systems. However, it is being revised, with a probable project completion of June 1985. In addition, electroplating design criteria is under development.

The construction of some of these complex facilities has been a problem. These projects require close inspection and careful control of material and equipment substitution change orders. Title II inspection procedure, using the design engineers or another engineering firm, should be requested by the EFD. Also, equipment acceptance tests should be coordinated with the design A/E and EFD.

Based on the lessons learned on these projects evaluated under the POE Program and some others evaluated previously, Guidelines for Industrial Facilities Projects (Encl (1) to NAVFACINST 4862.5B) were prepared. These attachment (1) guidelines should be followed from the initial conception of the project in the planning stage through design, construction, shake-down period, monitoring and certification.

ANALYSIS OF DEFICIENCY TYPES

Table 1

Facility	No. of Deficiencies	Sponsor	Criteria	Design	Construction	Equipment	Maint.	Other
Crane Ind. (IWT)	0	0	0	0	0	0	0	0
North Island (IWT)	29	0 0%	8 28%	5 17%	8 28%	2 7%	0 0%	6 21%
Jacksonville (IWT)	18	0 0%	4 22%	10 55%	1 5%	0 0%	0 0%	3 18%
Norfolk (IWT)	47	4 9%	2 4%	28 60%	3 6%	0 0%	1 2%	9 19%
Portsmouth (EP)	43	1 2%	5 12%	10 23%	13 30%	1 2%	3 7%	10 23%
TOTAL:	137 100%	5 4%	19 14%	53 39%	25 18%	3 2%	4 3%	28 20%

Analysis of Findings: To view these projects from the right perspective, the project POE teams looked at not just the deficiencies identified during the POE of the project, but the whole project history. Same of the major problem areas identified are described here.

- Cost Analysis: It appears, that the single most troublesome factor causing problems in these facilities is the unrealistically low cost estimate made in the early stages of these projects.

  For example:

NARF, Norfolk IWT Plant:	
Originally Programmed:	$1,009,000
Spent on Original Plant:	2,100,000
Upgrade Cost to Date:	5,200,000
Total to Date:	$8,309,000
MCLSBA, Albany, GA IWT Plant:	
Planning Study Cost Estimate:	$ 253,000
PCE Cost Estimate:	383,000
Designer Estimate:	457,000
Contractor Takeoff:	700,000
Low Bid:	926,000*

* After eliminating key elements of the plant, such as equipment redundancy, laboratory and office space.

When we underestimate the cost by a factor of four, we are actually asking the A/E to design the facility for 1 1/2% of the project cost when 6% is allowed and still unrealistic. In private industry, the design cost of an IWT plant is often 10-15% of the project cost.

- Automation

  One persistent technical problem, common in many Navy facilities, needs to be singled out. It is the degree of automation provided in the system. The rationale for a high degree of automation is usually that it reduces operator requirements at the plant. As indicated in the lessons learned part of this report, just the opposite appears to be the case. It was found at government and private industry facilities, that computerized control systems are costly, require constant attention, constant maintenance, and constant trouble shooting. Highly paid specialists are necessary to maintain both control and data-acquisition systems. A very common source of failure is the instrumentation that feeds process data to the computer. Therefore, total automation should not be attempted. What is needed is to automate (with complete manual back-up) time-consuming tasks, such as opening and closing valves, monitoring pH, ORP, change in pressure, operation of chemical feed systems, etc.

- Metal Recovery in Plating Shops

  One means of environmental control which the Navy has attempted to use on its hard chrome electroplating lines is a sub-atmospheric evaporative recovery unit. Simply stated, the unit is designed to recover chrome from the plating process and return it to the plating bath for further use. The Navy's first test evaluation took place at NARF Pensacola. The experience provided NAVFAC with valuable insight concerning the installation of environmental controls within a production shop. Among the lessons learned:

  - If an environmental control requires attention from production personnel, the Navy must have an up-front commitment from management that personnel will be dedicated to the task.

  - If environmental controls require changes in production methods, expect resistance. The Navy must demonstrate that the "new way" will benefit production as well as the environment.

  - The production side of the Navy does not necessarily feel direct responsibility for environmental protection. Many, though not all, Navy activities are shielded from the Navy's environmental requirements by public works departments and a financial structure which does not always recognize individual liabilities/responsibilities. For example, an activity can cause a Navy treatment plant to violate an effluent standard. However, even if the Navy pays a fine, the public works department accepts responsibility, and the activity is not held liable.

  The Navy has reinstalled the equipment at Charleston Navy Shipyard. At this time, the unit is functioning on the shipyard's chrome plating line, and is returning chrome to the plating bath. Since the unit is functioning, we have been able to evaluate its applicability and economic impacts. Preliminary results indicate the following:

  - The unit requires regular operator attention. We have had to replace worn valves, gaskets, and seals, and the Southern Division has developed a preventive maintenance and spare parts inventory to minimize down time.

  - The equipment appears to be economically unjustified, due in part to the relatively small amount of production at Navy activities, and the remaining need for end-of-pipe treatment for other wastes.

  - The availability of simpler, less expensive systems to achieve improved production and enhanced environmental controls.

In summary, the Navy's first attempt at metal recovery in a plating shop, though unsuccessful, did pave the way for future installation of alternate environmental systems. The Navy is now installing alternate systems in NARF Jacksonville, and is planning to install them in new plating shops.

- o Design. Often, as indicated earlier, the design of these facilities has not been totally satisfactory. It appears that this problem is often caused by the practice of hiring A/E firms without relevant experience. Therefore, we recommend that the Engineer qualification-A/E selection process described in attachment (1) be closely followed on IWT and EP projects.

Lessons Learned:

The following paragraphs summarize lessons learned from previous projects that need to be considered for all future projects. These lessons learned have been grouped into five categories: design factors, operational factors, equipment selection, material selection, and management.

1. Design Factors. The following points should be considered:

   a. Effluent discharge limits set by regulatory agencies should be evaluated closely and renegotiated with the issuing agency (if there is sufficient justification) prior to proceeding on facility plant design.

   b. Treatment operational requirements should be kept as simple as possible. Use instrumentation and controls only to reduce operating manpower requirements or hazard exposure. Highly automated control systems have not been successful at Navy facilities. The degree of automation should be optimized by balancing specific project factors. For example, a highly automated system which requires a few well-trained operators and considerable instrument maintenance must be compared against a system with less automation but greater operator attention. The degree of automation must reflect the specific Navy facilities staffing capabilities. In most instances, this will include automatic feed system, motorized valves, and other systems which minimize relatively simple treatment tasks.

   c. Operational considerations must be closely coordinated with waste treatment plant design in order to achieve an efficient and reliable facility.

   d. Collection sewers, pumping facilities, and all treatment tanks for acids and cyanides should be located completely separate from each other to avoid mixing and severe safety hazards. Facilities should be separate and designed so that spills or leaks could not result in cross connection between the acid and cyanide operations.

e. Leakage of industrial wastes or sludges from any container or vessel such as tanks, pipes, or sand drying beds must be avoided. Emergency drains and spill containment area drains should be provided.

f Waste treatment from plating operations should provide sufficient on-site storage capacity to allow for a minimum of eight (8) hours of plating operation during waste treatment shutdown periods.

g. Ventilation design must provide adequate air flow during normal and emergency conditions to assure a safe environment for operating personnel. This is particularly crucial in plant areas that generate chemical fumes and vapors. Covers for large volume reactors and equalization basins should be considered.

h. Provide positive head on all pump suctions.

i. Particular caution should be observed with chemical piping layout; for example, avoid entrapment areas for hydrogen peroxide which may cause valve and pipe eruption. Provide vacuum breaks in piping design to avoid undesirable back siphonage to pumps and tanks.

j. Provide adequate design of piping and equipment supports to avoid vibration which may lead to failure.

k. Provide for storage of process treatment chemicals in temperature controlled area.

l. Consider use of pneumatically controlled valves (rather than electric) in corrosive environments.

m. In the future, a much tighter and much more detailed specification for scrubbers and demisters is required to avoid naming manufacturers. The specifications should include the following:

- Requirement for packed tower type not for cross flow
- Requirement for minimum scrubber packing depth
- Requirement for minimum demister pad depth
- Maximum static pressure drop for scrubbers and demisters
- Requirements for access manholes for inspection and maintenance
- Liquid to gas flow rate
- Recycle water flow

- Sump size
- Spray nozzle location and size
- Reference to IGCI (Industrial Gas Cleaning Institute) Guideline Manuals for scrubbers and demisters

n. Design criteria for electroplating shop layouts, tank design, ventilation system design, etc. are badly needed. In-shop source control (segregation, recycle, reuse and good housekeeping) must be a major part of the design criteria. A design that facilitates maintenance and good housekeeping is very important.

2. Operational Factors. The following points should be considered:

a. Adequate operator training at facilities is mandatory. An operation and maintenance manual which specifically reflects the plant's requirements is also necessary. On-the-job training should be conducted at plant's startup and continued until the entire treatment process runs continuously and satisfies effluent discharge criteria.

b. Operation and maintenance manuals should be prepared for each equipment component in the plant. A system O&M manual should be prepared to integrate and demonstrate how each component relates to the system. Operation and equipment manuals should be updated after performance demonstration period to include equipment and plant modifications and new operational requirements implemented during startup or performance demonstration period. Contingency plans should be developed for plant shutdown and chemical spills.

c. Plant equipment should be operated immediately upon installation. Equipment should not be allowed to sit idle and deteriorate from lack of usage. Equipment performance should be in demonstrated compliance with specifications and testing procedures.

d. Operator work requirements should be minimized by designing for use of treatment chemicals in liquid form to be pumped or powder form to be automatically fed.

e. Use of computer control systems with total manual backup should be considered for larger installations.

f. A steam line/wand, or air supply, should be provided for cleaning filter press gaskets and flanges after removing solids from the units.

g. There is no reason for periodic dumping of plating baths. Normal contamination can be filtered out. The only way iron will contaminate a bath is when the current is reversed on the part being plated causing dissolution. That should never happen. For example, a chrome bath contaminated with iron can cost $20,000 to replace. In addition, the solution is highly toxic requiring special costly disposal, and chrome is a resource that is difficult to obtain.

3. Equipment Selection. The following points should be considered:

a. For solids separation following chemical precipitation (particularly plating waste), parallel plate or tube separators should be evaluated. Means of cleaning plugged plates or tubes must be provided.

b. Plate and frame filter presses have been particularly successful for dewatering chemical sludges for direct disposal and should be used unless special circumstances dictate otherwise.

c. Electrically powered agitators are preferred over air spargers. Mixer shafts should be constructed of solid corrosion-resistant materials rather than coated.

4. Material Selection. One of the most critical factors that has caused unfavorable conditions at industrial waste facilities operated by the Navy has been material selection and/or protection from the corrosive environments. Careful selection of materials is necessary. The following points should be considered:

a. Concrete block or masonry buildings are preferred over steel to resist corrosion.

b. Exhaust and ventilation ductwork must be structurally sound. Ductwork must have the proper materials to resist corrosive fumes vented or a corrosive atmosphere on the exterior side.

c. All piping and conduit material should be resistant to the corrosive agents and operating conditions to which it may be exposed. All exposed metal which is nonresistant to corrosion must be painted with a corrosion resistant paint. Effect of corrosive atmosphere on building interior roof and walls must be considered.

d. Tank materials (or liners) should be of proper corrosion resistant material.

e. Materials for seals, connectors, and gaskets on piping and pumps exposed to corrosive materials should be carefully selected to avoid damage.

f. All pump housing should be corrosion resistant.

g. All overhead piping which carries corrosive-type materials should be provided with a corrosion-resistant sleeve and directed to a safe area to avoid safety hazards from 1eaky piping. Provide emergency area floor drains.

h. Proper welding specifications and materials are necessary for constructing and/or repairing tanks and equipment which are exposed to corrosive materials.

i. Electrical boxes should be located away from corrosive environments. If located in corrosive operating areas, they should be sealed gasket types and corrosion resistant.

j. All other instruments and electrical equipment which may be exposed to corrosive environment should be protected. Control consoles, panel-boards, and transformers should be located within a closed and vented control room out of any corrosive atmosphere.

k. Concrete tanks or sewers exposed to corrosive materials should be constructed of acid-resistant concrete or provided with suitable liners.

5. Management. The following lessons should be considered:

a. An electroplater's job, of considerable complexity, is a low paying job requiring constant handling of hazardous and toxic substances in a hazardous environment. These platers, after taking considerable training on government expense, often leave their jobs for better paying positions. Therefore, it would be an advantage to the government to upgrade the job description and pay of the electroplaters that would result in a lower turnover rate; people with more motivation would stay in these jobs who would be more likely to comply with the important energy conservation and environment protection guidelines; and would reduce training cost.

b. In locations like an electroplating shop, the ventilation and lighting systems, and shop machinery create a very noisy environment. Therefore, there should be a noise abatement study as part of the Preliminary Engineering Study (PES).

c. Title II Inspection is not always the answer to inadequate inspection. There is always a chance that an unqualified person may be assigned to the job, or high turnover of personnel provides no continuity. It may be better to get the designer or project consultant to inspect the project construction on a once or twice a month basis and, in case of an upgrade project, to keep in touch with the operating personnel. As it was demonstrated on Norfolk NSY electroplating project, it pays to have good coordination between the electroplating consultant and operating personnel.

d. Repair and maintenance of an electroplating shop during the first year of operation can be a major problem. Often, complex and costly equipment, will not get the necessary adjustment, calibration, lubrication and repair because it is "under warranty". There is an attitude that the manufacturer is responsible to take care of this equipment during the first year of operation. Therefore, it is recommended that at least one mechanic be permanently assigned to the plating shop for preventive maintenance and repair. Also, the platers should do some of the simple maintenance tasks during low production times.

e. Because of recent major advances made in outfitting of electroplating shops and because of these shops handling hazardous and toxic materials to some very strict new regulations, "old" plating shops should not be upgraded. They should be replaced instead with new state-of-the-art designs.

f. For future plating shops, the type of air pollution control equipment and the degree of air pollution control must be addressed by the Navy. Since federal and state regulations do not address specific emissions limits for plating shops, the navy must direct the design engineer as to the level of control. NAVENENVSA Code 111C has recent stack tests from Long Beach Shipyard plating shop, which will help with identification of the quantity and quality of air emissions to decide the level of air pollution control for specific plating lines.

Conclusion: It is evident from the above that the acquisition of Industrial Waste Control Facilities and Electroplating Facilities has been a difficult process. To improve our record, the following is recommended:

1. Follow the Guidelines for Industrial Facilities Projects of: NAVFACINST 4862.5B.

2. Consider innovative acquisition routes, such as:

   a. Design, build and operate by contract.

   b. Request technical proposals from highly qualified firms. Accept bids only from those firms which submitted approved proposals.

3. Consider all the lessons learned, as summarized here.

4. Use the revised DM 5.8. For pre-publication copies, contact Code O4Bd, NAVFACENGCOMHQ.

5. Pay attention to detail:

Category Code of Facilities Affected:

831-09	211-14
831-14	211-24
831-15	211-31
832-30	211-41
832-40	211-51
227-35	211-61
213-49	211-73

Keywords:

Industrial waste, automation, control, design, operation, material, selection, material recovery, electroplating

GUIDELINES FOR INDUSTRIAL FACILITIES PROJECTS

References: (a) NAVFACINST 11010.44D
(b) CNO ltr Ser 454C/34394544 of 14 Dec 1983
(c) NAVFACINST 5100.11E
(d) NAVFACINST 11010.32F
(e) NAVFAC DN-5.8
(f) NAVFAC DM-3.15
(g) MIL-H-46855B
(h) NAVFACINST 11010.14N
(i) NAVFAC P-68
(j) NAVFACINST 11013.39

I. INTRODUCTION

A. INDUSTRIAL FACILITIES

Construction projects at shore facilities are initiated by the activities. The early investigations and preliminary engineering studies to define the needs and provide documentation for the Facility Study and DD Form 1391 development are the responsibility of the activity and its major claimant. From this point, after the project is included in a specific fiscal year program, Naval Facilities Engineering Command (NAVFACENGCOM) takes over and carries it through design and construction. After construction is complete, the facility is turned over to the user. This typical procedure proved to be inadequate for the more complex industrial projects. Therefore, to better serve the needs of the facility users, to ascertain that all aspects of the project are considered and to ensure that the facility is functioning as intended, a modified approach will be followed for industrial projects which involve complex processes or hazardous/toxic materials subject to regulation. This modified approach is described in the following guidelines. For a schematic, showing the sequence of events for projects which involve complex processes, see Figure 1.

B. These guidelines are intended for MCON projects; however, they also can be followed for non-MCON projects. The described team approach, with representatives from the activity, Engineering Field Division (EFD) and NAVFACENGCOMHQ, if needed, will be implemented. In addition, a few key projects, identified by NAVFACENGCOMHQ, will either be reviewed at NAVFACENGCOMHQ, or by a formally established acquisition team. For these projects, the guidelines provide submission requirements.

C. NAVFACENGCOM will execute a Memorandum of Understanding (MOU) with claimants to identify management procedures, specific project responsibilities and coordination procedures to be followed. As part of the MOU, the claimants will notify NAVFACENGCOM at a very early stage of the projects addressed here to allow the formation of the project teams after submission of Preliminary DD Form 1391 and inclusion of the project in the 5-year program. The formation of these teams and scheduling the preliminary engineering studies are EFD responsibilities. The major tasks of the project teams are shown on Figure 2. Also, this figure can be used to keep track of each project until completion.

D. Certain projects may not require or lend themselves to all of the provisions described below. Where doubt exists, guidance should be sought from NAVFACENGCOMHQ, Code 04B.

II. TECHNICAL CONSIDERATIONS

A. PRELIMINARY DD FORM 1391 SUBMISSION

The Preliminary DD Form 1391 Submission (PRELIM 1391) identifies and describes facilities required in support of an activity's assigned mission. The PRELIM 1391 is a predecessor of the 1391/Facility Study submission. The project submission includes the Preliminary DD Form 1391 and Supplemental Sheets (1391C) to provide essential Shore Facilities Planning System (SFPS) and programming information required for review, certification and entry of the project into the Military Construction Requirements List (MILCON RL). There are five additional components in the Preliminary DD Form 1391 Submission package. They are the pertinent Facility Planning Documents, an Economic Analysis, a site plan, an enviromental review and a cost estimate. See reference (a) series for guidance on the preparation of the PRELIM 1391 as well as on the criteria used in its validation for entry into the MILCON RL.

B. PRELIMINARY ENGINEERING STUDY

1. Close internal coordination on projects dealing with hazardous/toxic materials is essential. Therefore, beginning with development of a Preliminary Engineering Study (PES), which is required, a "team" concept shall be implemented. Members of the team shall be the activity, EFD, and, if necessary, NAVFACENGCOMHQ. Timely review of all project documentation by these team members is essential. As a minimum, codes familiar with design, construction and environmental regulations must be included as project team members.

2. After selection of project team members, the EFD shall conduct a PES for project definition and basis of design. A Preliminary Hazard Analysis (PHA), as required by reference (b), "System Safety Engineering for Facilities Acquisition", is to be conducted concomitantly and in conjunction with the PES. The PHA shall be considered as part of the PES. The PES, including the PHA, is a critical step in identifying and documenting deficiencies and problems and in developing firm cost estimates and viable alternatives. Timeliness is of the essence, since it will provide information needed for development of Form 1391.

3. As part of the PES, it is essential that consideration be given to source control, including the possibility of substantially altering a process or plant operation to reduce pollutant loading. By reducing the volume of controlled waste and the amount of contaminant, treatment units can be made smaller, and capital, labor and material costs can be reduced. Consequently, it is often economical to eliminate or reduce the quantity of controlled waste at its source prior to treatment or in lieu of treatment. Several possible techniques exist,

including improved housekeeping, process changes, material recovery and substitution, waste segregation and water recycle/reuse. Sometimes, with only partial purification, spent water can be reused in the industrial process. Water unsuitable for direct reuse may be serviceable for a different purpose in which quality requirements are less restrictive. Certain types of wastes should be kept separate until they reach the treatment plant, or even some advanced stage of treatment. For example, acid and cyanide wastes must be segregated for the sake of safety. On the other hand, the mixing of wastes may provide partial treatment, such as partial neutralization by mixing acid and alkaline wastes.

4. Preliminary estimates of additional staffing requirements for the proposed facility should be made as early as possible and furnished to the activity for budget and management purposes. Staffing estimates should be refined during the final design stage as discussed under IV.A.1.

5. There are often a number of alternatives which can achieve the desired result. Therefore, the major objective of the PES should be to determine what combinations of actions will be the most cost-effective, safest, and technically and operationally feasible, including whether process or plant alteration, or remedial treatment, or both, is the best course of action.

6. The PES shall be comprised of the following:

a. Description of industrial shop or treatment plant including processes employed
Location map
Industrial shop or treatment plant layout
Process flow sheets

b. Process and production data
Raw materials, chemicals, etc.
Production
Present: average, maximum, minimum
Future: average, maximum, minimum
Production patterns: daily and seasonal

c. Water Supply Survey: Identify water quality and quantity used in the specific industrial activity, including description, and water supply piping system layout. Water quality requirements (if known) for this specific industry should also be reported. This information may be used for wastewater recycle/reuse planning.

d. Waste Source Survey: If possible, identify sources according to the Standard Industrial Classification (SIC) Code, as identified by the Clean Water Act and the Clean Air Act.

(1) Waste sources
Description
Flow sheets
Industrial wastewater piping system layout

(2) Waste volumes and variations
Survey data
Estimated volume under conditions of average, maximum and minimum production, present and future

(3) Waste characteristics - physical, chemical, biological
Variations during a day, week, and season
Present, future

e. Air Emission Survey: Determine what air pollutants will be emitted by the proposed process and make a preliminary quantitative assessment of these emissions. Based on this data, establish the requirements of the preconstruction regulatory reviews, degree of emission controls needed and the monitoring/reporting requirements, if applicable.

f. Preliminary Hazard Analysis (PHA): See references (c) and (e).

g. Existing treatment/disposal methods.
Description of methods now in use.
Evaluation of these methods.

h. Effluent/emissions criteria applicable to discharge from a proposed industrial shop or treatment plant. Document the effluent standards necessary to meet NPDES permit requirements, pretreatment limitations and air emission criteria. When state or local limitations are much more stringent than Federal standards, the Navy (EFD Code 114) and regulatory agency should negotiate to achieve limits which are essentially consistent with the Federal program. Any deviations from the Federal program must be justified and fully documented. A copy of the standards and any resulting agreements should be included in the project documentation.

i. Source Control. Describe results of the investigations into the following:

Improved housekeeping
Process change(s)
Operation change(s)

Materials substitution
Material recovery
Water re-use
Waste segregation

j. Alternatives - compare using life cycle costs. Discharge to the base or publicly owned wastewater treatment plant should consider pretreatment requirements. Also, an assessment of contracted O&M should be included. Possibilities of air emissions trading or the bubble concept should be investigated.

k. Recommended solution(s) with rationale. Describe alternatives evaluated. Sludge generation and disposal must be a part of and may be a key factor in the recommendation. Include staffing and other logistics requirements for the activity. State whether a solution can be recommended without conducting treatability (see Section C) studies.

7. For selected projects, identified for NAVFACENGCOM or acquisition team review, send three copies of the draft final PES to NAVFACENGCOMHQ Code 04B for review. A 30 calendar day review period should be provided.

C. TREATABILITY STUDIES

1. It may be necessary to perform treatability studies (TS) to confirm the effectiveness of the proposed physical, chemical or biological unit processes. Pilot tests should be conducted prior to a chemical process design in order to determine the most cost-effective solution. The life cycle cost analysis for each viable alternative should include sludge handling, treatment and disposal requirements. More extensive TS, which may vary from bench-scale testing to on-site pilot plant operations, should be conducted when the PS justifies it. Justification for further TS may include:

a. When the PES recommended solution, or the feasible alternative, is not a proven "off-the-shelf" process.

b. When more than one unrelated process contributes pollutants to the effluent.

c. When unusual wastes are treated.

d. When wastes containing numerous interfering substances, such as stripping wastes, are to be treated.

e. When discharge limits are exceptionally restrictive.

D. PROJECT DOCUMENTATION

For Military Construction, Navy (MCON) projects, the PES, and TS if applicable, is to be included as a part of the facility study submitted with a DD 1391. For non-MCON construction projects, the PES shall be included with the step II submission. See reference (d) for guidance on the preparation of DD 1391.

E. PROJECT DESIGN

1. After the design is authorized but before synopsizing for CBD, the project team members will review all project documentation for current applicability and to ascertain that the project scope is sufficient to meet the latest applicable discharge/emission requirements. If revisions of the PES and TS are necessary, or if cost limitations indicate that no acceptable solution can be provided within budget, the project team will notify NAVFACHQ Code 05 without delay.

2. The scope of work for subject projects may require equipment redundancy and operation flexibility to provide continuing operation in case of equipment failure and to accommodate future changes resulting from new treatment standards, or variation in type, volume, and concentration of waste due to workload or process changes. Full in-place or stand-by duplicate systems or spare parts should be provided for all critical components, (e.g. determination based on the impact of the loss of the component on effluent quality) including reactors, tanks, valves, pumps, and piping, and if so indicated by specific hazard analyses. (Note reference (e). Holding and process tank sizing should provide an eight hour capacity allowance for storage during process flow interruptions. Flexibility should be increased by adding appropriate bypass lines. Proven technology and batch treatment should be chosen over continuous processes in accordance with reference (e), section 5.1.b.7. Air pollution control equipment will be provided in accordance with reference (f). Provisions shall be made for operator facilities such as lockers, male and female showers, lavatories, etc. All industrial shops and treatment plants will have office facilities, shop space, and assigned space for spare parts inventory and chemical storage. The control/operations building at treatment plants will also include a laboratory. To ensure that the safety and health considerations as well as operational failures and problems are addressed all through the project from concept development to disposal of the facility, additional and updated hazard analyses, as determined from the PHA, are to be conducted during the design phase. The design shall meet the applicable NAVOSH and reference (g) requirements. As indicated in the basic instruction, the Best Available Technology (BAT) requirements apply to these facilities.

3. The design phase will include preparation of conceptual design and project engineering documentation (PED) in accordance with reference (h) for projects in the MCON program. Submission of documentation, plans, estimates and specifications is also required at the pre-final and final stages of design.

4. At a minimum, the EFD Code 114 should review the conceptual design, the 35%, pre-final and final submissions. Also, as indicated in section I, a few selected projects will either be reviewed at NAVFACENGCOMHQ or by a formally established acquisition team. For these selected projects, the following sequence of submissions and reviews will be followed:

a. Concept Design submission. This submission will include: Design rationale, major equipment list, process flow diagram, proposed unit process sizing, material balances and applicable hazard analyses. Send three copies to NAVFACENGCOMHQ Code 043 for review and comment. The comments will be provided at the EFD review meeting.

b. 35% Design Submission. Send three copies to NAVFACENGCOMHQ Code 04B. Allow a 30 calendar day review period for this review, which is to be conducted concurrent with EFD and activity reviews.

c. Pre-final Design Submission. Same as for the 35% submission.

F. POST CONSTRUCTION AWARD SURVEILLANCE AND SUPPORT

1. Due to technical complexity, these projects will be inspected during construction by the design A/E or another qualified A/E (Title II inspection).

2. Construction support tasks for the design contractor will include all of the following:

a. Reviewing and providing comments on all proposed design changes to ensure consistency with process and material selection.

b. Conducting "change analyses" for all design changes, and for field changes, as applicable.

c. Providing assistance to ROICC during construction.

(1) Review and comment on shop drawings.

(2) Inspect field construction (Title II), unless another A/E is retained for inspection.

(3) Participate in acceptance tests for all major equipment items.

(4) Review construction change orders.

d. Observing and assisting the construction contractor in initial start-up for testing of the entire system, and providing necessary consultation to operating personnel for 90 days after completion of start-up and testing. This 90 day period applies to all projects except industrial waste treatment plants. (See paragraph I.l. for such plants)

e. Assisting the activity in the selection of qualifications/numbers of operators, providing training, and assisting the activity with ordering initial stock of spare parts and chemicals.

3. The EFD construction support tasks will include:

a. Assisting with construction.

(1) The project team will be provided documentation on all significant process and engineering changes and will be available for consultation.

(2) The project team will assist the ROICC with setting up component testing during construction.

(3) The project team will consult with NAVFACENGCOMHQ Code 051 on changes with significant cost impact.

b. Assisting with final inspection, and plant start-up using actual flows.

G. OPERATION

1. Because of the complexity of the equipment, instrumentation and control systems, the IWT plants will be operated by the construction contractor personnel during a one year (365 days) shake-down period after the Beneficial Occupancy Date (BOD). The operation of these facilities will include all of the following:

a. Setting up a Records Management System to handle records related to process control, effluent quality monitoring, reporting requirements, inventories for chemical supplies and spare parts, etc.

b. Setting up a Maintenance Management System, including schedules and procedures for routine adjustments, filter changes, and other preventive and corrective maintenance procedures as well as a spare parts inventory.

c. Setting up Laboratory Test Procedures and Schedules necessary to control the treatment works and comply with local, state and federal regulatory agency reporting requirements.

2. The contractor, after consultation with the design A/E, will make all routine adjustments and modifications necessary to make the plant operational. All changes will be documented and made available to the design A/E.

3. The contract for this one-year operation period will normally be bid as a portion of, or an option to, the construction contract, but is to be funded by activity O&M,N or NIF funds, as appropriate.

H. MONITORING

1. The operation of industrial facilities which generate or treat controlled wastes shall be monitored for the following:

a. To insure proper operation.

b. To gather data to satisfy control agencies as to compliance with requirements.

c. To gather backup data to be used with performance certification of a treatment plant.

d. To collect information which forms the basis for future improvements/additions to the industrial shop or treatment plant.

e. To validate/revise design criteria.

2. Certain industrial facilities require monitoring to comply with pretreatment standards if discharging to publicly-owned treatment works.

3. During the first year of operation, (the shake-down period), the cognizint EFD (Code 114) should request summaries of the operational problems and remedial actions taken at the industrial facility along with the monthly submittal of sampling and analysis data required by the local regulatory authorities. This information will assist the EFD in providing corrective actions, if required, and will also help NAVFACENGCOMHQ during a post-occupancy evaluation.

I. PERFORMANCE CERTIFICATION

1. In case of an Industrial Waste Treatment (IWT) plant, instead of the 90-day period for providing consultation to operating personnel, the design A/E shall provide observation and consultation to plant operating personnel for 365 days after the BOD. After the 365 days, the A/E shall:

a. Provide revised Operations and Maintenance Manuals indicating all the changes made at the plant and reflecting actual operating experience during the first year of operation.

b. Provide Performance Certification to the claimant/user stating that the plant will meet the applicable project performance criteria if the collected data so indicates.

c. Submit a corrective action report to the claimant/user if the project is not capable of meeting applicable performance criteria. The report shall include a schedule for undertaking in a timely manner the corrective action necessary to bring the project into compliance.

III. ENGINEER QUALIFICATIONS - A/E SELECTION

A. Design of adequate industrial facilities, including cost-effective treatment of wastewaters, requires the services of a highly competent professional familiar with industrial processes, and possessing the specialized knowledge of chemical, physical and biological principles applicable to the project. In addition, the ability to translate these principles into engineering plans and specifications is needed in order to arrive at a cost-effective solution.

B. To ensure that the A/E conducting the required studies, or performing the design has the above stated qualifications, the prospective A/E's must be screened for relevant experience and successful practice. The following steps are recommended, with selection to be in strict accord with reference (i), 5-303.

1. Ascertain that the synopsis prepared for publication in the Commerce Business Daily adequately describes the proposed project and spells out all special qualifications, including system safety engineering, and performance data which will be used as important evaluation factors. Commerce Business Daily Note 62 prescribes general selection criteria only. The drafting of particular evaluation criteria must be carefully done, tailored to the specific project.

2. The final selection should be based on a review of qualifications including performance data; interviews with the best qualified firms; availability of key individuals who will be assigned to the work; canvassing of past customers to determine their facilities' actual performance; and other relevant factors.

IV. OPERATIONS SUPPORT PLAN

A. An effective and economical support for these projects is necessary for their programmed life cycle. This includes responsibility for preserving continuity in the systematic planning, acquisition, and operation of the systems and equipment involved. Therefore, the Operations Support Plan for each industrial facility should include:

1. Activity Support

a. Staffing Requirements. As described under Preliminary Engineering Studies, Section II.A.4.,) staffing requirements for the proposed facility shall be determined as early as possible so that the activity will have time to program for them. Staffing requirements (number and grade/job levels, training and certification requirements peculiar to the system) shall be modified/confirmed during the design stage.

b. Funding Requirements. An estimate of funding support required by the activity (required in addition to personnel support in order to operate and maintain the proposed facility) shall be made by the design A/E as early as possible and furnished to the activity for budgeting purposes.

2. Collateral Equipment List. Concurrent with the design, a collateral equipment list shall be developed by the design A/E.

3. Operator Manuals/Instructions. Draft Operator Manuals/ Instructions shall be prepared during the design and construction stage and shall be available prior to initial start-up of the facility. The final detailed Manuals/Instructions will include sections on troubleshooting, emergency operations, taking samples, and identification of analysis procedures. The final Manuals/Instructions shall suit exact equipment furnished under contract.

4. Maintenance Manuals. Detailed Maintenance Manuals, including preventive maintenance procedures shall be prepared.

5. Operator Training. Hands-on operator training shall be provided by the construction contractor to the extent needed.

6. Contingency Plans. Specific procedures shall be prepared by the design A/E to deal with the event of a chemical spill or plant shutdown and shall be incorporated into the operations manual and the local activity spill contingency plan.

7. Spare Parts List. A spare parts (equipment) list shall be part of the project specifications when stand-by duplicate equipment is determined to be required but will not be connected in place.

B. The O&M Manual, Collateral Equipment List, Spare Parts List and Operator Training requirements shall be identified in project development stage and specifically listed in the project documentation.

V. OPERATING AND MAINTENANCE SUPPORT INFORMATION (OMSI) FOR MILITARY CONSTRUCTION PROJECTS

As stated by reference (j): "OMSI is a product, developed during the design and construction of a facility, needed to promote and maximize the efficiency, economy, safety and effectiveness of life cycle operation and maintenance of that facility." Among other complex projects, OMSI should be considered for heating and power plants, drydocks, maintenance shops, POL facilities and industrial waste treatment facilities. As stated by the instruction, any requirement for OMSI should be clearly indicated in the Military Construction Project Data, DD Form 1391, for MCON projects. OMSI will be prepared by the design A/E and amended during construction, as needed.

VI. FUNDING SUPPORT

Normally, the major claimant provides funding support for the Preliminary Engineering Study (including PHA) and for the Treatability Study which together define the project requirements. For some projects, pollution abatement funding may also be available for the PES and TS through the EFD. For MCON projects, MCON design funds are used to prepare plans and specifications after a project is included in a specific fiscal year program. Also, for MCON projects it is appropriate to use MCON project funds for OMSI, Collateral Equipment and initial supply of Spare Parts, and any design effort required after construction contract award, and for the preparation of operation and maintenance manuals where they are included in the project scope, and for specialized on-the-job operator training.

During the first year of operation of an IWT plants activity O&M,N or NIF funds, as appropriate, will be used for contractor operation costs and A/E support.

CASE P1 - Concrete Overlays on Concrete Pavements, M. Jones

Problem: Premature cracking of the overlay.

Symptoms: Corner cracking in aircraft wheel paths.

Collection of Facts: Concrete overlays on concrete pavements are designed using empirical procedures established by an American Concrete Institute (ACI) committee. Three types of concrete overlays are commonly recognized: fully bonded, partially bonded and unbonded. The required thickness of the overlay and consequently its performance under traffic is strongly dependent on the degree of bond established with the base pavement.

An unbonded overlay normally requires the use of a bond breaking course such as asphalt concrete or polyethylene sheeting between the base pavement and the overlay. This is intended to prevent the reflection of joints and cracks from the base slab into the overlay. The properties of the bond breaking course and its thickness are not taken into account when calculating the thickness of the overlay. The assumptions of the design procedure, however, require that the bond breaking course be kept very thin in order to obtain maximum structural advantages from the base slab.

In the design of a concrete overlay for a runway at NAS North Island, it was necessary to place a thick (greater than 1 foot) bond breaking course along the center lanes in order to raise grade. The bond breaking course selected was cement treated aggregate. The design agency calculated the required thickness of the concrete slab to be 6 inches using the unbonded overlay formula. The slabs were lightly reinforced and were 12 l/2 ft. by 20 ft. in size. The design loading was an Air Force C-141 having a gross weight of 320,000 pounds on a twin tandem landing gear.

Within 6 months of completion of construction, random cracking of the concrete was reported. Cracking was more pronounced in the aircraft wheel paths and was concentrated at the slab corners. A survey of the runway indicated that the cracking was predominantly in the aircraft traffic lanes. Slab warping measurements were also made which revealed that the slabs had taken a "dish effect". Slab corners were warped up and had lost contact with the underlying course.

Solution/Alternatives: An investigation of the cracking distress yielded the following conclusions:

1. Cracking occurred in the 12.5 ft. by 20 ft. slabs (length to width ratio of 1.6) primarily as a result of warping of the slab during the curing process.

2. The formula used to develop the thickness of a rigid unbonded overlay to an existing pavement may yield a slab thickness which hasn't the inherent strength or weight to resist significant warping, and that the warping leaves some exterior portions of the pavement unsupported.

3. The unsupported sections of the slab could not support the imposed aircraft loads and resulted in the cracking.

In order to prevent a reoccurrence of this type of distress the following guidance was issued:

1. The minimum thickness of separated unbonded overlays should be eight inches.

2. Joint spacing in unbonded, plain concrete overlays will be 12.5 feet by 15 feet.

3. When designing separated, unbonded overlays, rigid type separation courses such as lean concrete or cement treated aggregate should not be used.

4. When the thickness of the bond breaking course, due to leveling requirements, exceeds approximately four inches, the design equation for an unbonded overlay is not valid and the new pavement must be designed as a new slab on grade using a subgrade modulus (k value) not exceeding 500 pci.

CASE P2 - Granular Interlayers in Pavement Overlays, M. Jones

Problem: Improper use of granular interlayers in construction of overlays.

Symptoms: Pavement cracking.

Collection of Facts: When thick overlays have been required for increased load capacity, or where pavement grade must be raised, an interlayer of sand or gravel was frequently used between the existing and the new pavement wearing surface. Many pavements which were constructed this way cracked very badly due to water entrapment and high pore water pressure in the interlayer.

Solution/Alternative: The use of granular interlayers should be avoided when designing pavement overlays. When, for economy, their use is desirable, an open graded interlayer, with subdrains should be used. A preferred alternative is to stabilize the granular material with either asphalt or cement.

CASE P3 - Steel Fiber Reinforced Concrete - Airfield Pavements, M. Jones

Problem: Excessive cracking in new SFRC overlay pavements.

Symptoms: Corner cracking.

Collection of Facts: Steel fiber reinforced concrete costs from 30% to 50% higher than plain concrete. In order to be competitive with plain concrete on a square yard basis, SFRC airfield pavements have been designed to a thickness of three-fourths the thickness of plain pavements. Joint spacing has ranged from 25 to 50 feet.

Field surveys of SFRC overlay pavements has indicated that extensive corner cracking is occurring under load.

Solution/Alternative: When thin overlay pavements with long joint spacings are placed on rigid foundations, the corners tend to warp and lose contact with the base slab. Cracking then occurs under the aircraft wheel loads.

Indications are that the thickness design criteria is unsatisfactory. The thickness of SFRC pavements should not be reduced from that given by Westergaard theory and conventional overlay design methods. In no case should an unbonded concrete overlay of a concrete airfield pavement be thinner than 6 inches.

CASE P4 - Asphalt Slurry Seals on Airfield Pavements, M. Jones

Problem: Loss of cohesion in asphalt slurry seal mix.

Symptoms: Loose aggregate on pavement surface.

Collection of Facts: In August of 1976 the Atlantic Division of the Naval Facilities Engineering Command awarded a contract for approximately 1.4 million square yards of asphalt slurry seal on runways and taxiways at the

Marine Corps Air Station in Cherry Point, NC. Within about 8 weeks of the start of construction, and after 3 runways had been completed, aircraft operations reported the pick-up of slurry seal material on the undercarriage of the AV-8A (Harrier) aircraft. Shortly thereafter were reports of large "dust storms" whenever the Harrier operated near the surface.

Investigation by LANTNAVFACENGCOM engineers revealed that the slurry seals had lost cohesion and that wide spread raveling was occurring. The slurry seal was also stripping off the runway ends where it had been placed over rubber deposits.

Solution/Alternatives: One lesson learned from this project was that built-up rubber deposits must be removed before slurry sealing. Failure to remove rubber deposits may result in sheet-like stripping of the slurry from the pavement. After rubber removal a tack coat of emulsified asphalt must be applied.

Although the specification requirements appeared to have been met, as evidenced by submitted mix design information, no sampling and testing of the slurry mix had actually been accomplished during the construction process. The failure to exercise the quality assurance requirements of the specifications made it virtually impossible to know what actual mix proportions were applied to the pavements. The failure to sample and test the materials, or to merely retain samples for possible testing at a later date, made investigation of the raveling failures very difficult.

Under the direction of a consultant to the Navy, Mr. B. A. Vallerga, a number of cores were cut from the pavements and the aggregate stockpiles were sampled and tested. Based upon these tests as well as a review of other agency's experience with slurry seal, the most probable causes of the disintegration mode of failure were determined to be insufficient asphalt in the slurry mixture and a deficiency in the coarse and fine aggregate fractions.

In order to correct the raveling problem, a series of trial fog seal applications with varying application rates was undertaken. The remedial treatment which was eventually applied consisted of 0.10 gal/sq.yd. of a 1:1 dilution of SS-1h asphalt emulsion. The emulsion application was followed by 3 passes of a rubber tired roller with 90 psi tire pressure. The fog seal was successful in preventing any further raveling.

CASE G1 - Subsidence of Soil at the Naval Research Laboratory, M. Yachnis

Problem: Unexpected subsidence of soil during an excavation.

Symptoms: Progressive settlement of soil under the moving load of a Caterpillar D-6 Bulldozed.

Collection of Facts: A geotechnical company was engaged to perform soils investigation at the site of a proposed very sensitive building. The general trend is to minimize the number of soil borings and spend as little money as possible in geotechnical investigations. In this case, the depth of borings was adequate but the number unreasonably small for the size and the sensitivity of the building. The subsurface conditions were described in the soils report as favorable for pile foundation system. The contractor proceeded to perform a shallow excavation by using earth moving equipment, The operation started smoothly, (see Fig. l), until a Caterpillar D-6 bulldozer started sinking due to settlement of the soil (see Fig. 2). A detailed subsoil investigation concluded that, prior to the failure, a number of cavities of various size existed at the proposed building site which were not uncovered during the original soil investigation. An extensive soil boring program was undertaken and most of the cavities were uncovered.

Solution: The cost of soil borings is minimal in comparison with the total construction cost. Particularly in special structures, where small deflections and settlements are critical, extensive geotechnical evaluation imperative. The number of soil borings must be reasonable enough to insure comprehensive knowledge of the subsurface conditions.

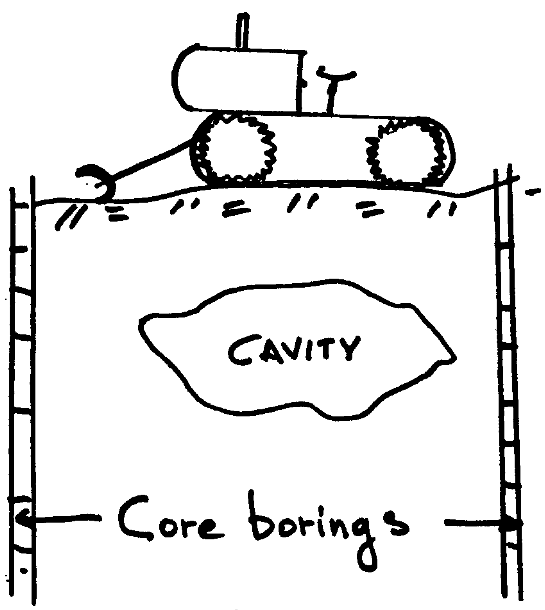


Fig. 1

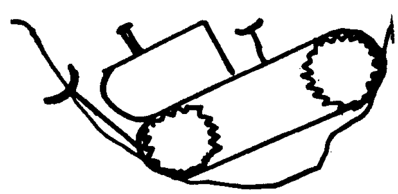


Fig. 2

CASE G2 - Failure of Concrete Caissons, M. Yachnis

Problem: Failure of concrete caissons and difficulties during caisson placements due to existence of underground obstructions at the Naval Regional Medical Center, Bethesda, Maryland.

Symptoms: During placements of concrete caissons to be used as foundation of the new replacement of the hospital facilities, distress of caissons was observed due to unexpected underground obstructions. Based on the soil borings, geotechnical consultants could not provide a reasonable explanation of the difficulties encountered during the driving of the caissons.

Collection of Facts: A number of caissons was retrieved from the ground and carefully observed. It became obvious that the driving was performed through hard material equivalent to solid rock. It was recommended that a test pit be opened to visually examine the sub-soil conditions. Large utility, sewer, and water lines, and electrical conduits were uncovered which were the cause of the problem. The unexpected extensive obstacles resulted in considerable time delays and very expensive change orders.

Solution: It is imperative to map all existing utilities-water, sewer, and electrical-which must be included in the bid-package.

CASE G3 - POL (Petro-Oil-Lubricants) Facility at Naval Air Station, Sigonella, Sicily, M. Yachnis

Problem: Failure of the steel plate at the bottom of three 4500 barrel fuel tanks.

Symptoms: Upon completion of the project and before filling with fuel, the steel bottom plates buckled and warped (See Fig. 1). Cracking also occurred in several areas of the steel plates.

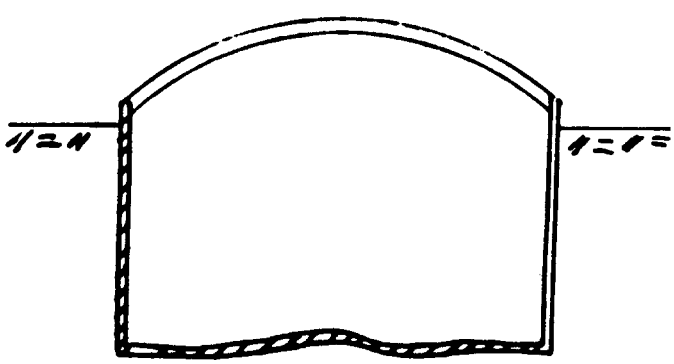


Fig. 1

CASE G3 (continued)

Collection of Facts: Upon inspection of the site, it was apparent that an upwards force had caused the failure. A geotechnical evaluation revealed a water table close to the ground elevation. However, the tank was designed without consideration of the uplift force due to hydrostatic head. Therefore, no provisions for anchorage of the bottom were made.

Solution: One of the most critical loading conditions of any structure below the water line is hydrostatic pressure. This pressure is applied on the side of the structure as well as upwards on the bottom. Various solutions were taken into consideration. The basic elements included gravity weight and an anchoring system to counteract the uplift and a method to repair the buckled plate. The most cost effective and reasonable solution was to provide a concrete slab anchored to the bottom of the tank (See Fig. 2).

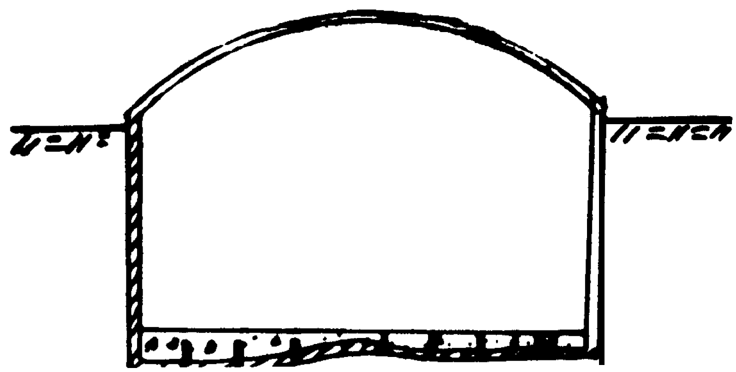


Fig. 2

CASE G4 - A Foundation Failure in Compressible Soils, M. Jones

Problem: Inadequate foundation design and improper pile placement.

Symptoms: Differential settlement

Collection of Facts: In designing and building a structure on soft compressible soil, a number of errors were made. Some of these errors were:

1. Designing and building a 4 inch non-structural floor slab on top of 7 feet of densely compacted fill overlying a deposit of soft silt and clay varying in thickness from 4 feet to 70 feet.

2. Failure to consider negative skin friction in determining required pile capacity.

3. Piles were permitted to bear in the compressible clay soil rather than being driven to underlying limestone.

As a result of these errors, large differential settlements were experienced in the floor and in the columns. The distress was so severe that part of the structure ultimately had to be demolished and rebuilt.

The seven feet of compacted fill on this site surcharged the compressible soils and induced differential settlements. Within two years, 8 inches of differential settlement was observed. Although the Architect-Engineer had specified "Fill material shall be placed as soon as possible to consolidate the subsoil---", the plans did not call for an engineered surcharge with settlement plates and a formal monitoring program. Settlement resulting from the fill also induced a negative skin friction on the piles which exceeded the specified pile capacity.

The plans required eight piles to be test driven with capacities calculated by pile driving formula. Six piles failed to meet the required driving resistance; thus additional length of pile and pile splicing packages had to be ordered. The A/E permitted the 65 foot long piles which were on site to be driven full length while awaiting delivery of the additional piles and splicing kits. Upon resumption of driving, two to three weeks later, the piles could not be driven deeper due to a soil freeze effect. Driving resistances were very high and consequently the A/E accepted the frozen piles and approved the driving records.

Solution/Alternative: For this site, a structurally supported floor was necessary. Another alternative may have been an engineered surcharge with sand drains.

Negative skin friction on piles results from the downward movement of the soil, relative to the pile. Failure to recognize the presence of negative skin friction can result in overloaded piles and unacceptable settlement. Methods for assessing this "downdrag" are given in DM 7.2. For this structure, the downdrag loads could have been accommodated in the design, however, the A/E failed to recognize its presence.

Piles were permitted to bear in a compressible soil strata due to mis-interpretation of driving resistance and failure to understand the nature and variability of the sub-soil. For a site with soil conditions as poor as this one, and with 80 production piles to be driven, at least one pile load test was required. Piles should not be terminated in a compressible soil strata.

Interpretation of pile driving records must be under the supervision of a Geotechnical Engineer.

CASE G5 - Expansive Soils, M. Jones

Problem: Expansive clay subgrades.

Symptoms: Heaved floor slabs.

Collection of Facts: Expansive clay soils, if not properly controlled, can swell and cause significant damage to structures. In one project, which was "over the money", the lime stabilization of the subgrade was deleted as a cost reducing measure. The decision was made without review of the geotechnical engineering study. Soon after construction, after an extended rainfall, floor slabs heaved and were substantially damaged. The cost of repair was many times the amount saved by deleting the lime stabilization.

Solution/Alternative: Identify expansive characteristics with Atterburg Limits, soil activity, and consolidometer tests during the geotechnical investigation. For limited areas such as directly under building slabs and shallow foundations, the most effective control is through removal and through replacement of the expansive soil with compacted granular fill. The depth of removal can be determined by plotting a profile of the percent expansion against depth (see DM 7.1). For areas of wide extent, such as highway and airfield pavements, lime stabilization is the preferred method of treatment. The tendency to swell can also be partially controlled by increasing the soil moisture to near saturation and reducing the compactive effort.

CASE G6 - Sheetpiling/Bulkhead Replacement, A. H. Wu

Problem: Sheetpile bulkheads are extensively used in the Navy's shoreline environment. Many bulkheads have markedly deteriorated. Some of them are beyond repair, while in other cases, the deterioration has been more moderate.

When a bulkhead shows extensive corrosion and deterioration, remedial work is required. Repair could be accomplished by either welding steel plates to the corroded sheetpiles, or covering them with cast-in-place concrete panels. However, installing a new sheetpile in front of the existing one, and joining the two by a tie-rod, is probably more cost effective. This bulkhead replacement method can be employed if the existing bulkhead has moderate deterioration, and the structure is in stable condition.

In the NAVFAC DM-7.2 [2], Chapter 3, Analysis of Walls and Retaining Structures, a free-earth support method is described. Fig. 1 shows the free-earth support method adopted by the Navy.

Until now, the free-earth support method has been generally used in bulkhead replacement design. However, there are some difficulties with this approach: (a) it commonly assumes that the existing bulkhead has neither usable value nor supporting capacity even though the structure is to remain in-place, (b) values of the soil strength parameters are conservatively assumed, with the common result of an overdesign calling for excessive sheetpile length, unnecessarily large steel section modules, and an anchor spacing closer than necessary. If the soil is a weak soil, replacement of bulkhead by the free-earth method is impractical and uneconomical.

Symptoms: Corrosion, deterioration, subsidence and failure of bulkhead.

Collection of Facts: To determine the extent of bulkhead deterioration, field inspections were conducted by the Navy at many Naval Stations. Some important findings were:

(1) Corrosion of sheetpiling occurred mainly in the low tide range, between El. 0.0 to -3.0 ft.

(2) Evidence of deterioration was seen on the side faces and webs of the Z-sections, where honeycomb type cavities and large holes had developed. In most cases, there was a clear and consistent pattern. A band of heavy corrosion appeared in the low tide range, from below the mean low water line to 3 ft below.

(3) Below the low tide range and down to the mud line, corrosion appeared to be relatively light. Corrosion in the upper tide range and splash zone was moderate.

(4) Anchor-rod and wales generally showed very little corrosion.

Fig. 2 shows the condition of an anchored bulkhead after 25 years in service. Fig. 3 shows the corrosion on a sheetpile 28 years of age. As a result of the field inspection findings, the Navy has designed and constructed replacement bulkheads by driving a new sheetpile in front of the old sheetpile and connecting the two by a tie-rod. This design method was used recently at the U. S. Naval Station, Annapolis, Maryland. In 1942, a bulkhead was built, consisting of 232 section sheetpiling, double channel wales, steel tie-rod, and timber pile anchorage. In 1976, it was found that deterioration had occurred in the intervening 34 years. The damaged bulkhead was replaced by installation of new 227 sheetpiles in front of the old sheetpiles. Fig. 4 shows the actual bulkhead replacement.

Solution: Rather than replace corroded sheetpiles, it may be more economical to drive new sheetpiles a short distance, say, 3 to 4 ft, in front of the existing sheetpiles. To calculate the supporting effect of the old sheetpile, the method of stability analysis can be modified. Fig. 5 shows a scheme of the bulkhead replacement. The modified stability analysis and design procedures are presented as follows:

(1) Calculate the active earth pressure, P_a, to a depth of D_{min} which is about 20% shorter than the depth D.

(2) Assume 60% of the anchor-rod's yield strength will be available to resist an overturning force, or use the anchor rod pull force calculated from the free-earth support method. If earthquake induced dynamic loading is to be included in the design, then 75% of the anchor-rod yield strength may be used.

(3) Calculate the weight of backfill, W, placed between the new and existing sheetpiles.

(4) Calculate the passive earth pressure, P_p, from the assumed penetration depth D' which is equal to D_{min}.

(5) Use Equation (1) to determine the stability against overturning about Point B. If the factor of safety is less than 1.50, increase the depth D'. The stability safety factor can be also increased by increasing the new sheetpile distance d.

$$F_s = [(Ap)(D'+h_w+h_2) + (W)(d/2) + (P_p)(l_p)]/(P_A)(l_a) \text{....Eq. (1)}$$

(6) Use the same type of sheetpile and the same size of anchor-rod for the new structures.

(7) Connect the top of the existing sheetpile to the new concrete deck.

The following steps are recommended to assure a proper design.

(1) Take enough soil borings to accurately estimate the subsoil conditions. Preferably, the spacing of the soil borings along the bulkhead line should nut exceed 50ft.

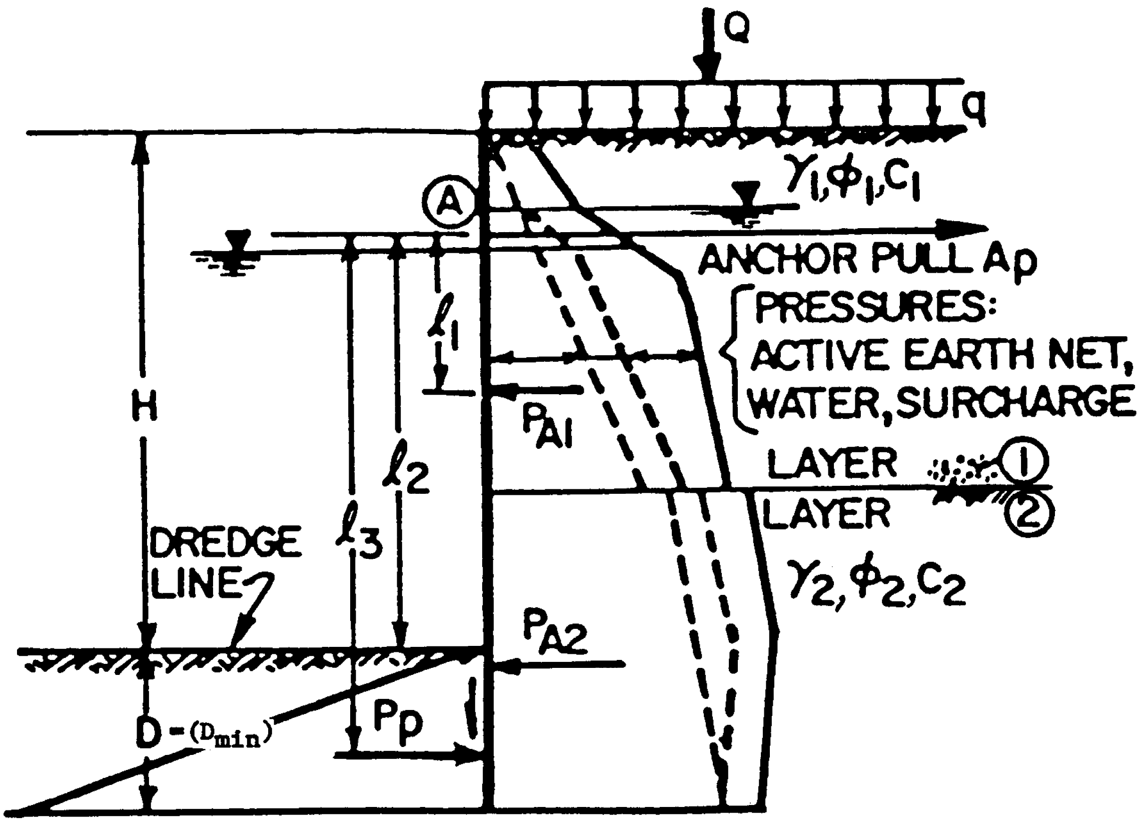
(2) Perform soil laboratory tests on undisturbed soil samples to determine shear strength parameters accurately, as they are essential to the bulkhead design. Consolidated undrained triaxial shear tests are recommended, if there is no dredging.

(3) Inspect the existing structures, i. e. sheetpiles, wales, tie-rods, and anchorage system by diver and by excavation of test pits to verify that the supporting capacity of the existing structures can be included in the design. The validity of this depends on an accurate assessment in this regard.

(4) Check earthquake loading requirements. If the bulkhead is an important structure and the earthquake induced loading is critical to the bulkhead, the earthquake load should be included. One approach for this case is to use the total stresses, in lieu of the effective stresses, to compute the active earth pressure against the sheetpile. In this dynamic loading case, the anchor-rod working stress may be increased to 75% of the yield strength and the required safety factor against overturning may be assumed somewhere between 1.3 and 1.2.

COMMENTS:

If an anchored bulkhead has corroded after many years of service, but is structurally stable and field inspection revealed that the anchorage system is in good condition, then a cost effective replacement method may be adopted using the above method. The new sheetpile need not be installed deeper than the existing sheetpile unless dredging in front of the new wall is needed.



FREE EARTH SUPPORT – GENERAL CASE

- * DEPTH OF PENETRATION REQUIRED: TAKE MOMENTS ABOUT POINT (A) AND SOLVE FOR D: $P_{A1} l_1 + P_{A2} l_2 = \frac{P_p}{F_S} l_3$

  F_S = 2 TO 3 FOR COARSE GRAINED SOILS

  F_S = 1.5 TO 2 FOR FINE GRAINED SOILS
- * ANCHOR PULL: $A_p = [P_{A1} + P_{A2} - P_p/F_S]\ d$, d=ANCHOR SPACING
- * MAXIMUM BENDING MOMENT ($M_{MAX.}$) IN SHEETING COMPUTED BY THE FREE EARTH SUPPORT METHOD AND APPLYING P_{A1}, P_{A2}, P_p/F_S AND A_p. FOR SHEETING IN SAND APPLY MOMENT REDUCTION FOR FLEXIBILITY.
- * INCREASE PENETRATION COMPUTED (D) BY 20% TO ALLOW FOR DREDGING, SCOUR, ETC.

(From NAVFAC DM-7.2, Design Criteria for Anchored Bulkhead, pp 7.2-88)

Fig. 1. Anchored Bulkhead Design Method

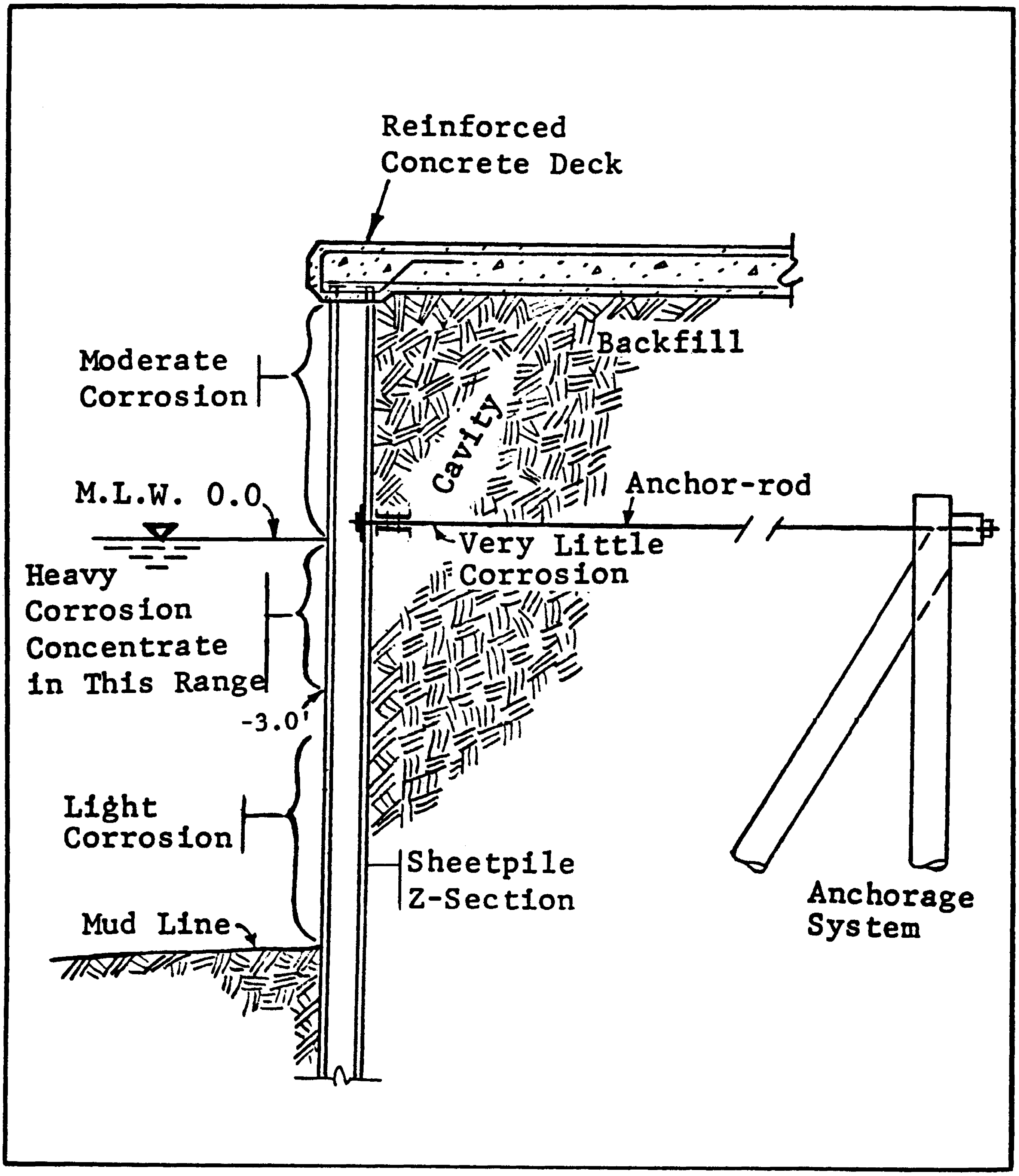


Fig. 2. Anchored Bulkhead After 25 Years in Service (Ref. 3)

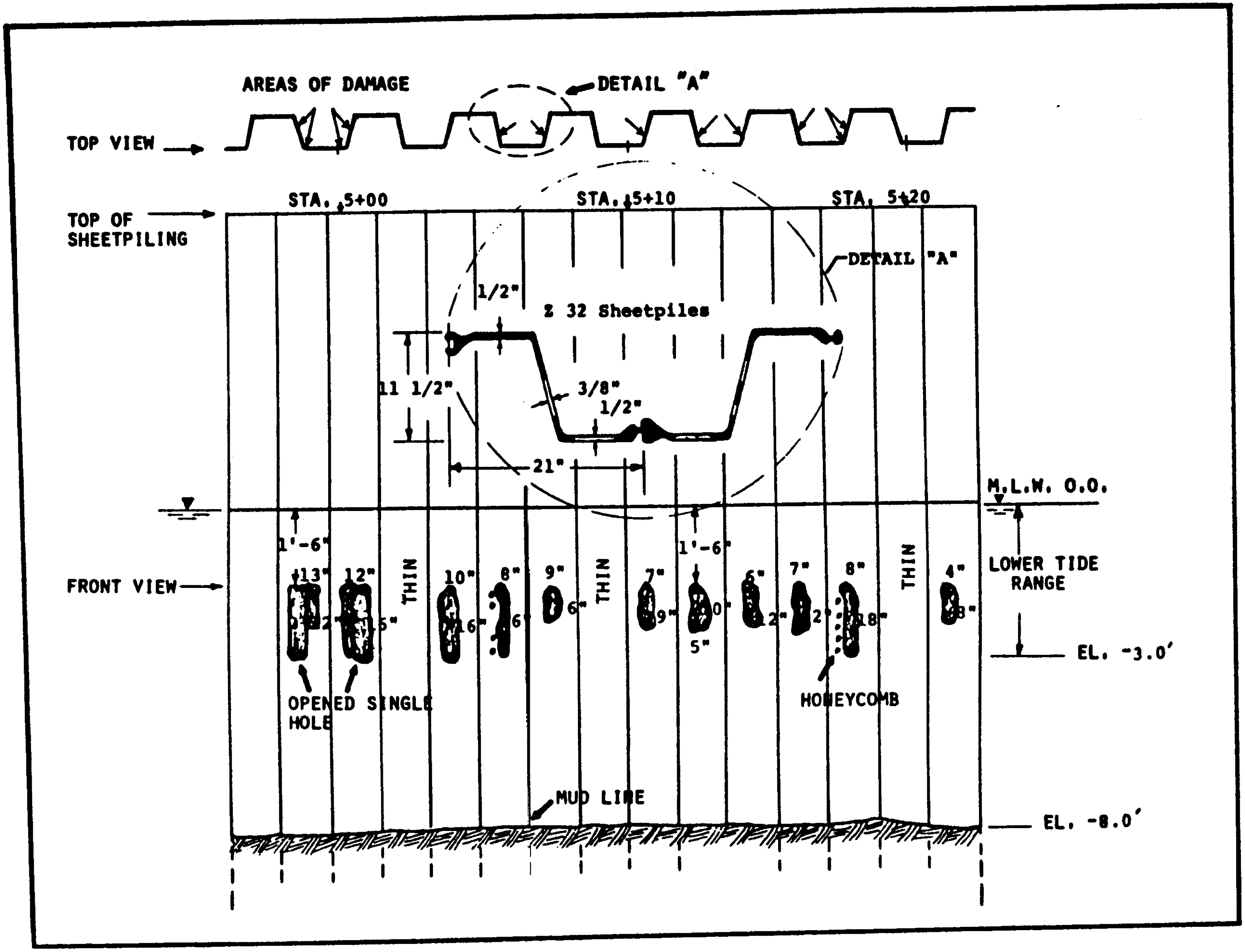


Fig. 3. Sheetpile Corrosion After 28 Years in Service (Ref. 3)

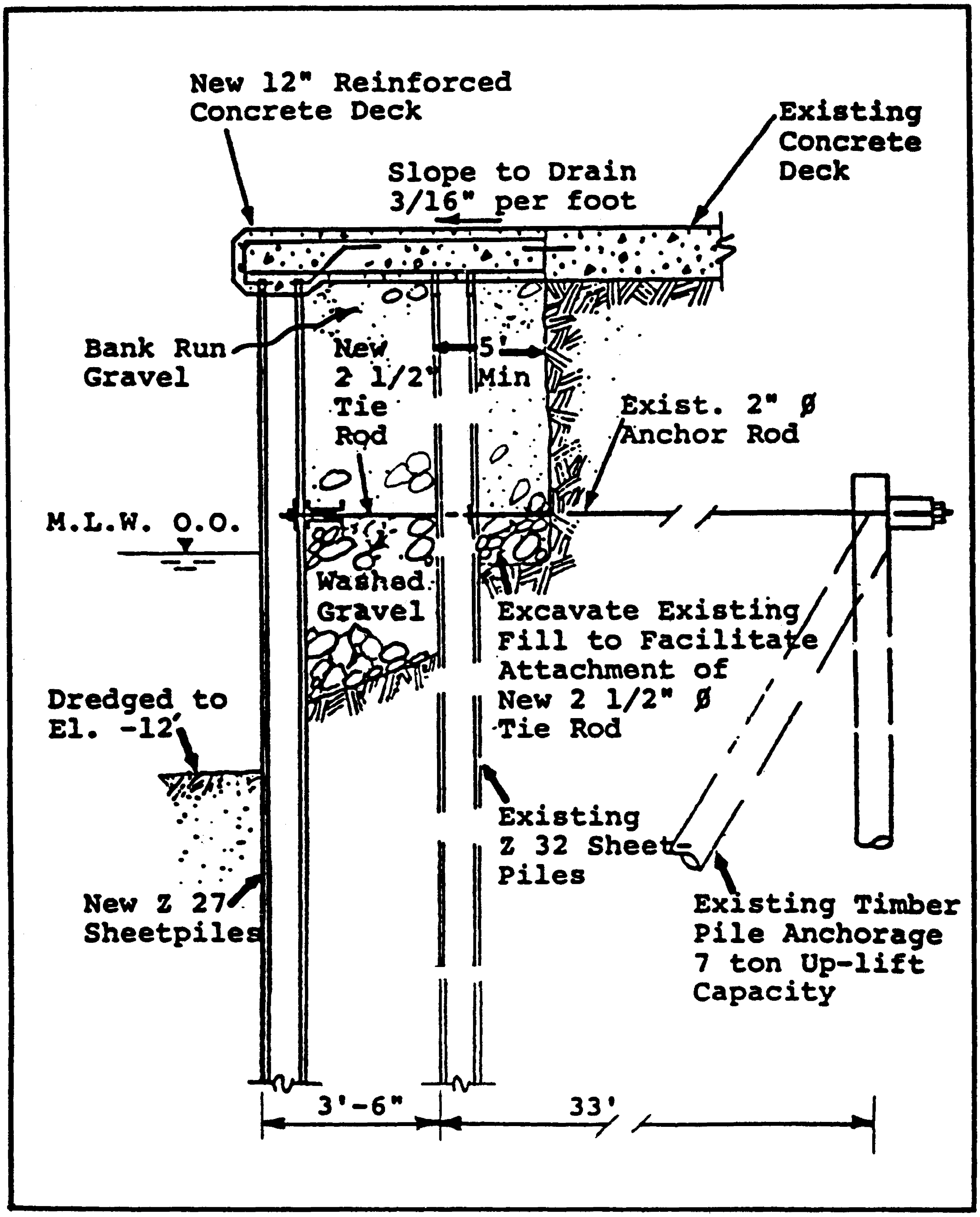
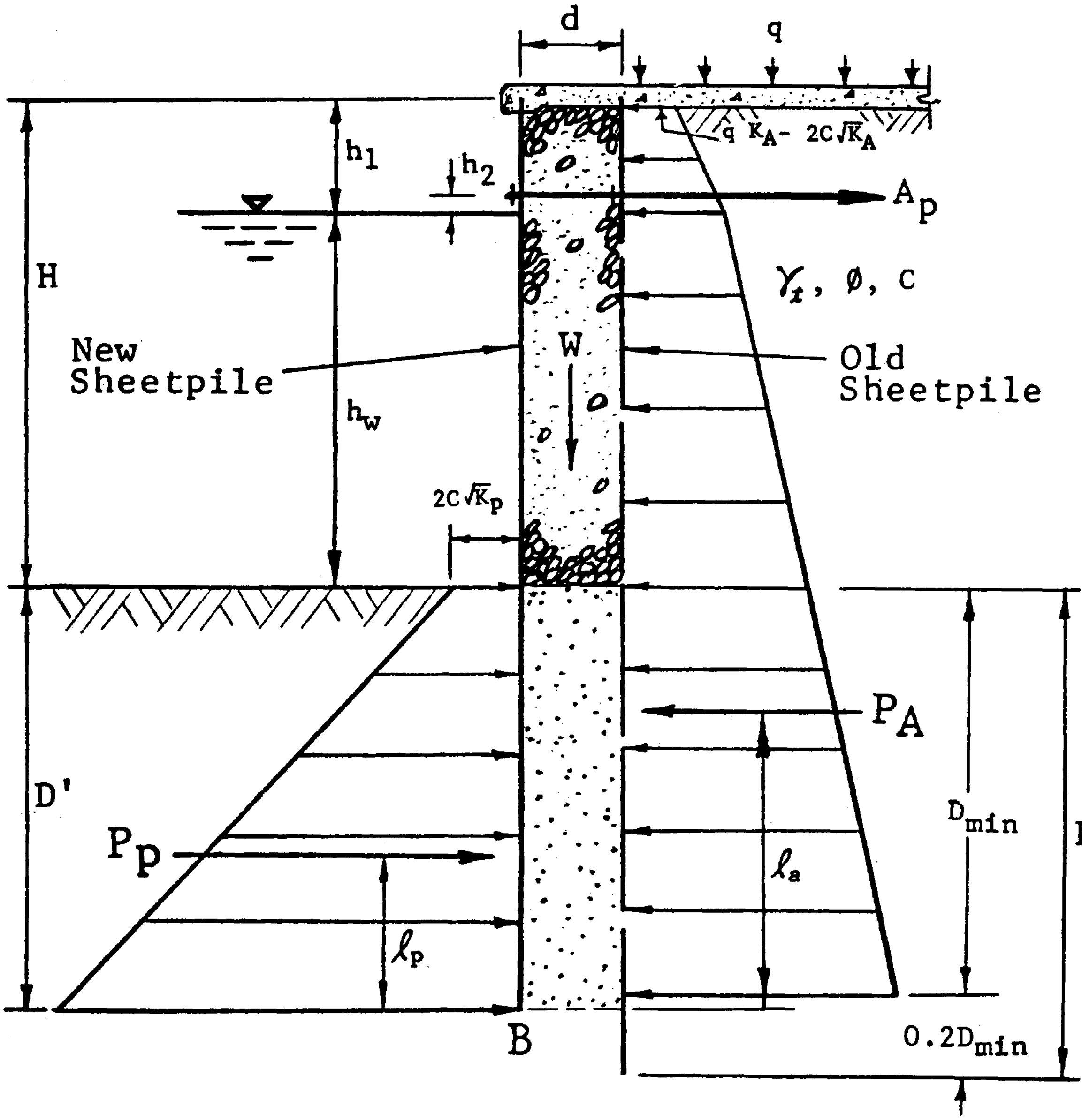


Fig. 4. Bulkhead Replacement, U. S. Naval Station Annapolis, Maryland (Ref. 3)



Factor or Safety Against Overturning @Point B

$$F_s = \frac{A_p(D'+h_w+h_2) + W\cdot\frac{d}{2} + P_p\cdot\ell_p}{P_A\cdot\ell_a}$$

Fig. 5. Stability Analysis for Bulkhead Replacement

CASE G7 - Lateral Earth Pressure and Structural Adequacy of Drydock Wall, A. H. Wu

Problem: Determination of earth pressure and the structural adequacy of the walls of an existing drydock (Mare Island Naval Shipyard, Drydock No. 3)

Symptoms: Elementary analysis indicating structural inadequacy.

Collection of Facts:

1. The methodology for determining dynamic loading acting on a massive drydock wall, which retains submerged backfill, has not been well established or verified.

2. Previous analyses did not consider the following which affect the stability of the wall against lateral pressure:

a. Two rows of closely spaced timber piles support the outer crane rail surrounding the dock. The configuration of these piles should attenuate the effect of the postulated seismic induced dynamic earth pressure.

b. The rail support beam of the outer rail is tied to the top of the wall by a series of struts. The rail support beam, pile caps, struts and piles constitute a system which will restrain the top of the wall and resist lateral movement and overturning.

c. Total liquefaction of the soil behind the walls is not likely to occur and therefore, it should not control the analysis of the structure.

d. It is reasonable to assume tension potential in concrete, when a seismic safety evaluation against a postulated risk of an existing concrete structure is made.

Solution:

1. Take concrete core samples at the critical plane to determine the tensile and compressive strength of concrete. (Approximate cost of sampling and testing is $15k)

2. Conduct field check to determine if reinforcing steel exists around the flooding tunnel by using a pachometer (reinforcing steel locator).

3. Install two strong-motion accelographs; one on the drydock and the other at a free field location in the Navy Yard. (Approximate cost of installation by NCEL is $6k)

4. Perform periodic surveys of wall movement and rotation during the dock flooding and dewatering cycles. (May use tiltmeter)

5. Annually and after each earthquake of magnitude five or greater on the Richter Scale, record cracks, if any, in the wall and floor of the drydock, pumphouse and tunnels equal to or greater then l/8 inch in width.

The above methodology was implemented and it was verified that the drydock wall was structurally adequate.

CASE G8 - Pile Driving Problems, A. H. Wu

Problem: Difficulty in driving piles as required by the specification.

Symptoms: The following difficulties were encountered during installation of cast-in-place pipe pile at Physical Education Center, U.S. Naval Academy.

1. Pile damage resulting from overdriving.

2. Piles cannot be driven to anticipated depth.

3. Piles do not achieve anticipated resistance.

Collection of Facts:

1. The pile driving criteria was excessive and resulted in overdriving of the piles. Consequently, damage occurred in some piles.

2. There were three pile load tests available for this project. However, the load test results and the associated pile driving records were not fully used to develop the driving criteria. The existing criteria relied heavily on very high dynamic blow counts. This tends to overstress the shell pile during deep driving which causes pile deformations and driving difficulties.

3. The pile driving criteria, even though it is excessive, was established for a pile to carry 60 ton allowable bearing capacity. However, it appears that only a few of the piles are requiring 60 ton bearing capacity (many of them require between 40 to 50 ton capacities. Tension piles in the pool areas to resist uplift force are believed to need lesser capacity). It is incorrect to use a 60 ton pile driving criteria to control all the pile installation when many of the piles do not require 60 ton capacity.

Causes:

1. Excessive pile driving criteria.

2. Unusual and/or inhomogeneous site conditions.

3. Improper test pile program and interpretation of test results.

Solution: It is important to correct the pile driving criteria so that overdriving can be avoided and pile damage can be eliminated. This, of course, will result in a government cost saving. In this regard, it is suggested that:

a. Driving criteria should be adjusted to accommodate actual bearing capacity needed. Namely, different driving criteria for 40, 50, and 60 ton piles can be used.

b. For 60 ton pile capacity, the driving criteria should be modified to read that: "Piles shall be driven to a depth where the dynamic blow counts shall be greater than 10 blows per foot for at least 20 feet."

c. If the pile/deep foundation system will cost more than 20% of the project cost, or if it will cost more than $100,000, then as soon as a contract is awarded, the EFD's or NAVFACHQ's geotechnical engineers should be notified, who will work with the ROICC during the pile driving and pile test operations so that knowledgable personnel are involved at an early stage.

CASE G9 - Landfill Stabilization, Naval Academy, A. H. Wu

Problem: The U.S. Naval Academy is engaged in modernization and expansion of its educational facilities which included construction of the multimillion dollar Nimitz Library and Rickover Hall. To Support the Nimitz Library, a landfill of about 3.5 acres was constructed along the Dorsey Creek in 1970. The Nimitz Library is founded on cast-in-place concrete pipe piles which are partially embedded in the landfill.

Before the filling, the elevation of the area ranged from -3 to -20 ft. Soil borings showed a deep layer of soft organic clay averaging about 55 ft thick underlying the fill site. Analysis indicated that this clay soil, which has low shear strength and high compressibility characteristics, would not safely sustain the weight of ordinary fill necessary to raise the grade to about +5 ft. The measured shear strength of the clay was 150 to 350 psf.

To complete the expansion on schedule, the landfill material used was lightweight oyster shell to lessen instability of the embankment and to reduce settlement. Vertical sand drains were then installed to accelerate consolidation of the underlying clay material. The landfill was completed in September 1971.

Symptoms: The fill surface showed large and rapid subsidence. The rate of subsidence was far greater than the settlement anticipated from consolidation of the soft clay soil. A careful inspection of the Nimitz Library structure revealed cracks in some of the pile caps and girders.

Collection of Facts: Subsequent investigation of the problem revealed that excessive fill movements were aggravated by overloading of the upland area during construction of Nimitz Library and Rickover Hall. The lateral movement appeared to have caused additional earth pressure to the piles embedded in the fill area, thus creating a potential for structural damage to the library building. The large settlement which occurred in the landfill made the area unusable. Fig. 1 shows the potential of instability with existing site conditions.

As an emergency solution, about 2 to 3 ft of upland fill was removed in March 1974 to prevent general slide of the landfill embankment. After removal of the fill, the vertical settlement declined from about 1.25 inches a month to 0.25 inches a month, while the maximum lateral displacement slowed from about 0.30 inch/month to 0.10 inch/month. The rate of movement, however, remained the same through 1975.

Lowering the fill grade resulted in the area being flooded whenever a high tide in the creek occurred, and vehicle access was lost. However, without first improving the stability of the entire landfill, it could not be restored to its original level.

Solution: In February, 1977, remedial work to stabilize the landfill started. The stabilization method included application of several techniques:

1. A counterweight was applied at the tow of the fill slope and the slope was flattened to confine the entire fill area. A stone berm was constructed

in the creek and restored the slope to l:10. After this, the stability of the landfill, in terms of safety against sliding, will increase about 705, according to idealized slope stability analysis.

2. A pile supported bridge was built to convey traffic around the most critical area, and a pile supported seawall was constructed at the perimeter of the landfill. Following this addition, the stability of the landfill will increase about 120% by avoiding traffic loads.

3. The weight on the upland was reduced by removing the heavyweight fill from the area and replacement with lightweight slag fill. After this change, the stability of the landfill increased about 110%.

The soil stability analysis was made at the most critical section. It was estimated that after the remedial work, up to 3 ft of settlement is expected to occur in the fill during 30 years. Therefore, the parking areas and roadway on grade were designed to accommodate the expected settlement by using flexible unit block pavers. It will permit differential settlement, provide effective surface drainage, and will be aesthetic in appearance. Surface drainage was accomplished by a grid of dry well catch basins. The remedial work provided an adequate factor of safety against dangerous lateral movement of the fill. This has been verified by monitoring of movements previously described.

Other features of this project included application of a precisely controlled construction sequence and monitoring system to minimize disturbance of the landfill and to observe fill movements during construction. The sequences of construction specified and implemented were:

a. Install 15 tell-tale tripods in Dorsey Creek to monitor and avoid a mud wave during stone berm filling.

b. Place stone berm at the toe and on the slope of the embankment evenly.

c. Drive H piles for seawall and bridge support according to a specified order.

d. Construct pile caps, seawall and bridge.

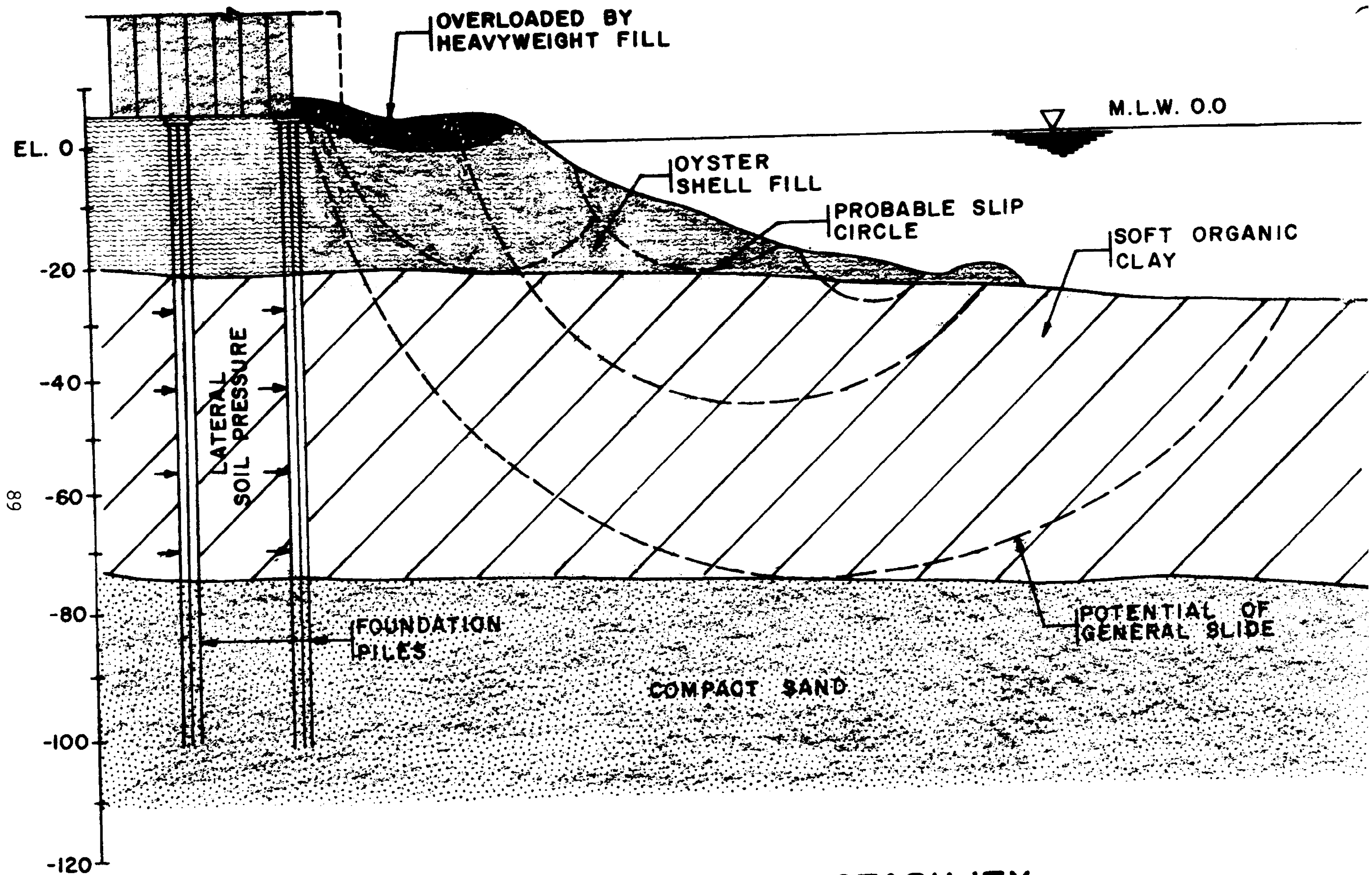
f. Replace heavyweight fill on the upland area with lightweight slag.

h. Place flexible pavers and dry wells for drainage on the parking areas.

Fig. 2 shows a section of the landfill with remedial work.

The monitoring system has included taking continuous readings on the tripods in the creek, observation points on the library building, settlement platforms on the fill, and slope indicators in the fill. The grades of stone berm placed underwater were checked by sounding periodically during and after the stone filling.

The main landfill stabilization work was essentially complete in March 1977. The stabilization method used in this project has, so far, proven successful. The progressive lateral movement of the fill toward the creek has been arrested. The danger of such movement, which occurred particularly to the library building, has been eliminated. The landfill area has been restored as a fire vehicle access route and as an aesthetically pleasant site conforming to the surroundings of the Naval Academy environment.



POTENTIAL OF INSTABILITY WITH EXISTING SITE CONDITIONS

Fig. 1

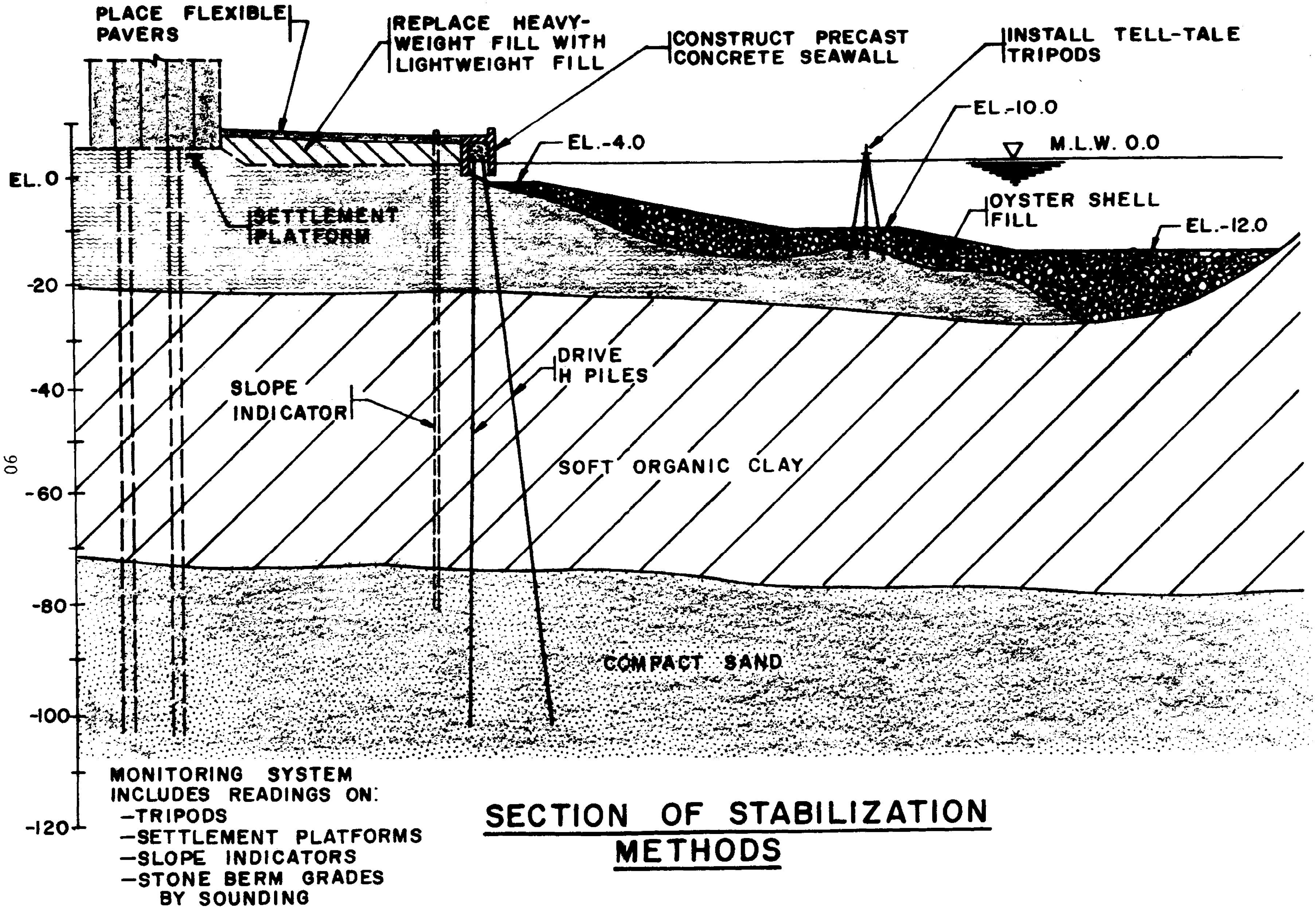

PLACE FLEXIBLE PAVERS
REPLACE HEAVY-WEIGHT FILL WITH LIGHTWEIGHT FILL
CONSTRUCT PRECAST CONCRETE SEAWALL
INSTALL TELL-TALE TRIPODS
EL.-10.0
EL.-4.0
M.L.W. 0.0
OYSTER SHELL FILL
EL.-12.0
EL. 0
SETTLEMENT PLATFORM
-20
-40
-60
-80
-100
-120
DRIVE H PILES
SLOPE INDICATOR
SOFT ORGANIC CLAY
COMPACT SAND
MONITORING SYSTEM INCLUDES READINGS ON:
-TRIPODS
-SETTLEMENT PLATFORMS
-SLOPE INDICATORS
-STONE BERM GRADES BY SOUNDING
SECTION OF STABILIZATION METHODS

Fig. 2

CASE G10 - Foundation on Compacted Fill, A. H. Wu

Problem: Economic design of foundation for buildings located at the Anacostia Naval Station.

Background: In 1976, a $2.2 million automotive maintenance facility was constructed on a compacted structural fill placed over a very thick compressible clay layer. The facility, designed by the Naval Facilities Engineering Command, is located east of where the Anacostia River meets the Potomac River.

A large land area has been reclaimed here since 1884. The subsoil conditions of this filled land consist of deep deposits of soft silty clay extending typically to a depth of 60 ft. Because of the weak soil conditions, pile foundations had been used exclusively to support structures built in the fill areas in the past.

Use of conventional pile foundations at the new facility would have been very costly. Furthermore, they would have resulted in the recurring operational and maintenance problems associated with the differential settlement between the pile-supported buildings and the adjacent fill supported side-walks, driveways, and landscaping.

The project consisted of three separate one-story buildings. The maximum wall load was 5 kips per linear foot, and the maximum bearing wall span is about 140 ft. Since the project site is located in a flood plain area, the master plan required the building sites to have a finish grade at about 6 ft above the original surface, which was at about elev, +4.0. Parts of the building areas were located over an old concrete pavement.

At first, the project faced two major foundation problems: (1) the probability of large overall settlements along with differential settlements, and (2) the possibility of excessive foundation cost.

Symptoms: High cost of foundation.

Collection of Facts: The soil boring indicated that the site subsoils consisted of 4 ft of recent medium dense silty sand fill, 55 to 60 ft of soft silty clay with slight organic content, and then a dense silty sand extending to 120 ft depth. The results of soil testing showed the silty clay material to have been normally consolidated and to have high compressibility characteristics.

Consolidation test results were used to predict the rate and magnitude of the settlement which would occur from the weight of the fill required to raise the grade. Computer settlement analyses indicated that the ultimate settlement resulting from the fill load alone was approximately equal to 33% of the height of the fill placed. In other words, to raise the grade 6 ft, about 9 ft of fill would be necessary (allowing up to 3 ft of settlement). The rate of consolidation would be so slow that preloading the site with surcharge to accelerate the consolidation settlement would not have been an effective solution.

To use pile foundations to avoid large settlement of the buildings would have cost $400,000 just for the piles alone - too high for the $2 million budget. Furthermore, support of these buildings on piles, while allowing the surrounding ground to subside, would create operation and maintenance problems.

To use sand drains along with preloading by surcharge to accelerate settlement would require a long waiting period for a substantial settlement to take place. Furthermore, this method was not economical. To promote a uniform settlement of the building areas, a reinforced-earth application of geotextiles was considered for footing foundation reinforcement. However, there was insufficient experience with this technique to warrant adoption at that time.

Solution: A foundation system consisting of strictly controlled engineered fill placed on a firm stone base and inverted "T" shaped footings was then considered for the support of the buildings. Detailed computer assisted settlement analyses for this compacted structural fill scheme further indicated that: (1) the compacted fill would impose the most significant settlement-inducing load, and subsequent building loads would have much less influence on the settlements; (2) the post-construction settlements would probably maintain a uniform rate; and (3) about 75% of the estimated total settlement would occur over a period of 20 years. It was concluded that a compacted structural fill, which would act as a relatively rigid mat, could be placed over the thick clay soil to support the proposed buildings.

To promote a relatively uniform settlement of the compacted structural fill, a 2 ft thick layer of crushed stone, ranging from 2 to 6 inch in size was placed on the existing ground to increase the overall rigidity of the fill. In the areas where the concrete apron existed, the concrete was left in place to substitute for the crushed stone base. The 7 ft high controlled fill was then placed in layers and compacted to the final grade (elev. +13).
Fig. 1 shows the compacted structural fill scheme and the typical subsoil conditions.

Earthwork specifications required that the fill material should not have a liquid limit exceeding 25 or a plasticity index exceeding 8, and should not have any organic matter, or any brick or stone larger than 6 inches in size. This fill material was mostly available within a quarter of a mile from the project site, as the Naval Station was once used for stockpiling earth excavated from the Washington Metro Subway construction. According to the Unified Soil Classification system, this fill material was generally classified as SC (clayey sand) or SM (silty sand), with some amounts of CL (low plasticity clay) material. A substantial cost saving was made by using this material as the structural fill. The specifications called for the structural fill to be compacted to at least a dry density of 117 pcf. The fill was placed in 8 inch loose-lift thickness and uniformly compacted by means of a combination of a sheepfoot roller and a vibrating smooth drum roller. Each layer of the compacted fill was tested by the sand cone method. Field density test results showed that about 87% of the test results met the compaction requirements, which was considered acceptable. Thus the compacted structural fill was able to support 2,000 psf footing pressures.

The footings were designed as inverted "T" shaped grade beams. These inverted "T" shaped footings were sized and reinforced to provide the strength required to carry the superstructure. The structural system for the superstructure is load-bearing masonry walls and open-web joists for the partial second floor and the roof. This structural system was selected as the most economical in light of the aesthetic constraints on the exterior finishes imposed by the facility master plan.

The masonry walls are not flexible in terms of accommodating differential settlements. The wall footings, however, were designed to be rigid enough to bridge over or otherwise resist differential settlements in the event that the footing lost support for a span of 10 ft such as at a building corner. Considering the potential footing subgrade problems, the inverted "T" beam footing size and reinforcing were selected so as to provide the strength and effective moments of inertia required to resist footing deflections. This design limits the differential settlements experienced by the masonry walls to a tolerable range. The floor slab was reinforced both in the top and in the bottom of the slab. It was cast directly on the surface of the compacted fill, and was set on and tied to the inverted "T" shaped grade beams at the edges. This was done to ensure that the floor slab would continue to settle at the same rate as the building walls, and to prevent the slab from remaining somewhat buoyant while the building footings and superstructure settled.

To control the quality of the compacted fill work and to monitor the consolidation of the soft, silty clay stratum, 15 settlement plates were installed on the existing ground surface to monitor the settlements during the compacted structural fill work. The settlement plates were observed weekly throughout the two-month compacted fill placement, and monthly during the 18-month facility construction period. After construction, settlement readings were made at a lesser frequency ranging from three months to yearly by March 1981. Observations were made by reading elevations on steel plates and pipes placed on original grade.

Four pneumatic piezometers, consisting of wellpoint and pore water pressure sensing elements, were installed after completion of the compacted structural fill to evaluate the pore water pressures developed in the clay material from the fill and building loads. The piezometer readings showed that the pore water pressures dissipated slowly, and were leveling off at a rate which was consistent with the rate of settlement. They provided a good correlation between the actual and predicted rate of settlement.

The construction of this project began in August 1976. The average settlement which had occurred by the completion of the compacted fill work was about 2 inches. Construction of the building was completed in June 1978. The average rate settlement measured after completion of the buildings was about 3 inches per year, about 16% higher than predicted by analytical results. From the beginning of the project to March 1981, the average and maximum settlements were about 1.3 and 1.5 ft respectively. No wall cracks or structural distress of the buildings have occurred to this date.

Designing structural foundations to accommodate the effects of large settlements is a real challenge to engineers. The risk of foundation failure or building damage can be minimized if the foundation system is designed in such a way that it can promote a uniform settlement over the building area.

For construction of a structure with a shallow foundation system on a weak subsoil, it is essential that the foundation settlement rate and magnitude be properly predicted and that settlement be closely monitored during construction. With a well conceived and executed foundation and superstructure design and appropriate field control, a safe and cost-effective shallow foundation system can be constructed even on difficult subsoil. This has been demonstrated by the entirely satisfactory performance of this facility even though large settlement has occurred.

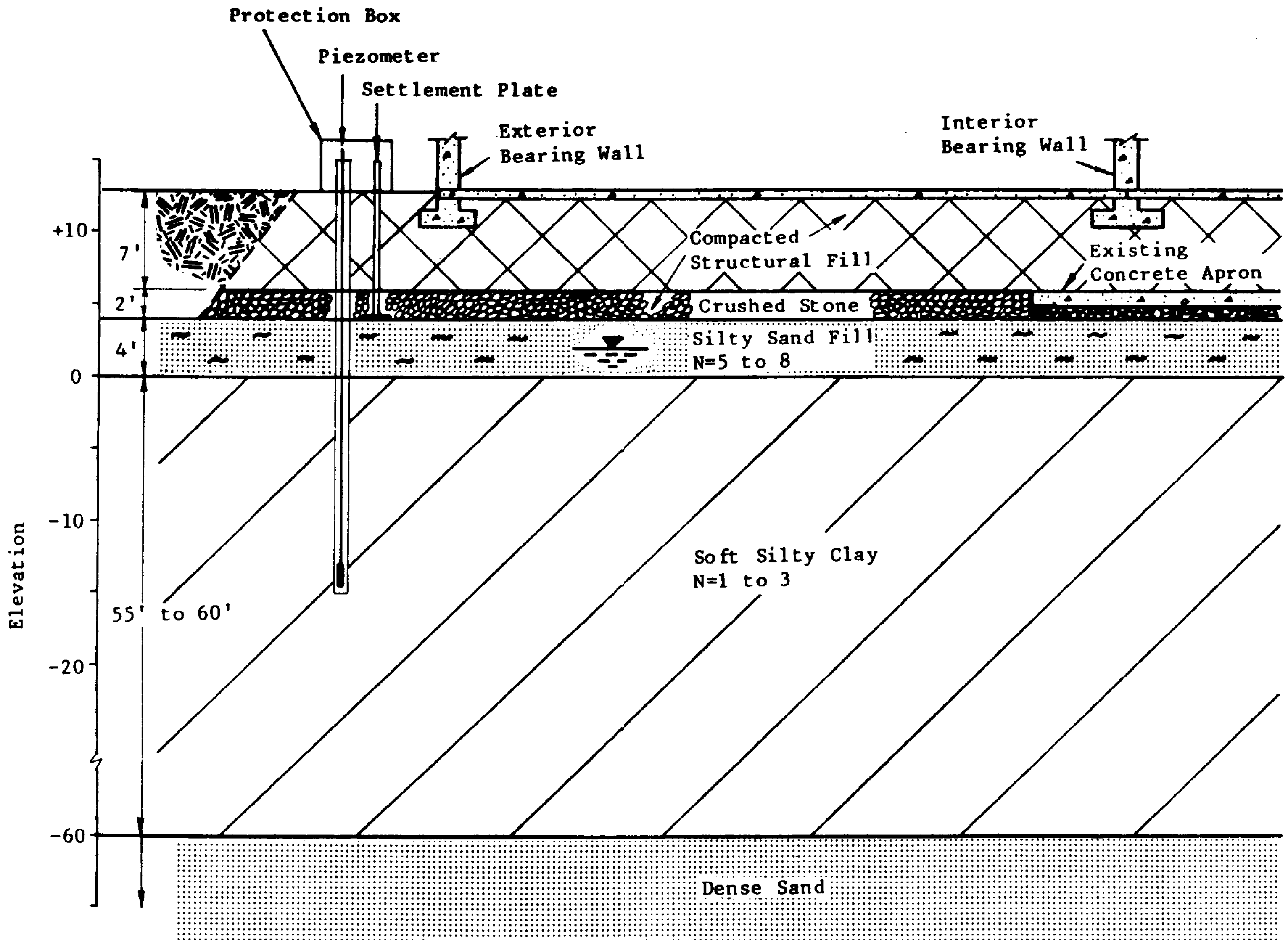


Fig. 1. Compacted fill was placed on a two feet thick layer of crushed stone. In the area where concrete apron existed, it was left in place to substitute for crushed stone base. Foundation soils are 4 feet of recent medium dense sand fill, which is underlain by 55 to 60 feet (17 to 18 m) thick, highly compressible clay.

CASE G11 - Failure of Timber Pile Foundation, NRL, M. Yachnis, & J. V. Tyrrell

Problem: Distress in structure, failure of timber pile foundation at Bldg. 43, Naval Research Laboratory.

Symptoms: Gradually diagonal shear cracks and tension cracks developed in reinforced concrete beams and horizontal tension cracks in columns. Differential settlement became evident.

Collection of Facts: Observation of the cracks indicated that the cracks on the beams were generated by reversal of stress - Fig. 1. The cracks in columns were caused by lack of pile support which resulted in the adjacent framing supporting the column instead of the column supporting the structure with the lower column and pile caps creating a tension load - Fig. 2.

Exploratory pits were opened to check the timber piles and concrete pile caps. The timber piles under the structural members which had experienced cracks were found deteriorated and in some cases the upper portion was completely decayed. After an extensive exploration at various locations of the piles, the problem area was isolated. A large diameter sewer pipe runs along the deteriorated piles. The leakage from and infiltration to the pipe was the apparent cause of the deterioration.

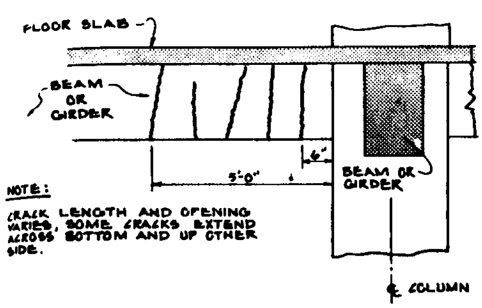


Fig. 1

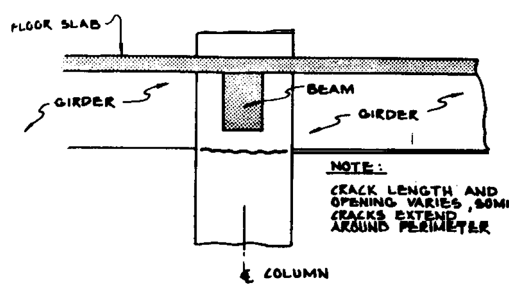


Fig. 2

Solution: Possible causes of reinforced concrete beam and column cracking are overloading, underdesign, material deterioration and poor quality of materials. In addition, such in the above case, investigators should check for foundation settlement, pile deterioration and failure in caps.

CASE POL 1 - POL Storage Tanks, Spark Generating Equipment, R. Thomas

Problem: Perpetuated myths in and around full storage tanks concerning spark generating equipment.

Symptom: Unnecessary costs and job delays while trying to obtain specialized equipment. Injuries from using non-ferrous tools with less strength.

Collection of Facts: The American Petroleum Institute (API) has issued 3 safety documents covering the most commonly misunderstood areas concerning spark generation:

1. API-PSD2214 - So called "non-sparking" (non-ferrous) tools offer no more degree of safety over ordinary ferrous tools.
2. API-PSD2213 - Subscriber type (Bell) telephone systems cannot generate enough power for fuel ignition and therefore are suitable for Class 1, Group D atmospheres.
3. API-PSD2212 - Flashlights containing 3-cells and less cannot generate enough power for ignition and therefore do not need to be explosion proof.

Solution: The API safety documents are endorsed by NAVFAC and can be referenced along with NAVFAC MO-230 when performing maintenance around fuel facilities.

CASE POL 2 - Thermal Expansion of Fuel, R. Thomas

Problem: Excessive pressures from thermal expansion of fuel downstream of pressure control valve even though system contains a pressure relief valve (PRV).

Symptom: Bulging or bursting of pantograph fueling hose and leaking swivels.

Collection of Facts: When an angle pattern PRV is used to relieve thermal pressure buildup from downstream to upstream around a block valve, the spring relief setting on the valve can be misleading if the upstream piping remains under pressure. The actual relief pressure becomes the value of the spring plus the upstream pressure which is also acting on top of the valve. For example, if the PRV has a 150 psi spring setting and the upstream pressure holds at 170 psi, relief will not occur until 150 + 170 = 320 psi is obtained, which may damage the hose.

Solution: Either relieve to an unpressurized line (return line) with the PRV, or incorporate a thermal relief check valve around the shut-off valve to relieve upstream. In stainless steel, the relief valve runs about $400 while the thermal relief check is about $50.

CASE POL 3 - Tires for Refueling Vehicles/ FOD Hazard, R. Thomas

Problem: Stones being picked up in the tire treads of aircraft refueler trucks and dropped on the aircraft parking apron, creating a F.O.D. (Foreign Object Debris) hazard.

Symptom: Engine damage to aircraft and G.S.E. (Ground Support Equipment) turbine engines due to F.O.D. pickup by air intake.

Collection of Facts: Due to the location of many Navy refueler fill stands, and the roads traveled by refuelers, stones are picked up in the truck tire treads. When anti-F.O.D. tires are used, tread life is short, and there is still some stone pickup which must be removed.

Solution: Field tests have been initiated and completed at NATC Patuxent River using "racing slick" type recap tires on refuelers. They carry no F.O.D. and results show about l/3 more tire life than threaded tires. Traction has proven to be excellent in all types of weather-rain, ice and snow. Stations and contract refuelers now have the option to go to "slick" tires and feed-back from the field is showing similar good results. Commercially, Dulles Airport is now using "slick" tires on their "people movers" to transfer passengers from the terminal to the aircraft out on the flight line.

CASE POL 4 - Failure of Filter/ Separators, R. Thomas

Problem: Failure of filter/separators (F/S) to coalesce water at aviation refueler fill stands.

Symptom: Premature shut-down of fuel flow by fuel contamination monitors during water overload.

Collection of Facts: During recent fuel facility surveys at Navy and Marine air stations, it was noted that when stations converted from top loading to bottom loading fill stands, lubricated swivels and valves were reused. Due to their age, some had leaks and a way to stop the leak was to pump grease into the fitting. Unfortunately, some grease works its way into the fuel and in effect "wets" the coalescencers and prevents the "beading" or "coalescing" of water droplets. With a faulty or slow acting slug, valve water can then pass through the F/S and cause premature shutdown of fuel monitors at the fill stand or on the refueler trucks.

Solution: Replace all lubricated valves and swivels at aviation refueler fill stands with non-lubricated type. (As required by NAVFAC DM-22).

CASE POL 5 - Pressure Relief Valve (PRV), R. Thomas

Problem: Difficulty in determining whether a Pressure Relief Valve (PRV) is opening or is stuck in the open position when relief piping is hard connected into remote waste tank.

Symptom: Premature filling of waste fuel holding tank with good fuel.

Collection of Facts: Frequently Filter Separator (F/S) water discharge piping and PRV piping from F/S and distribution piping is hard piped into a waste holding tank. When waste tank starts filling with fuel prematurely, it becomes almost impossible to determine where the fuel is coming from.

Solution: Install sight glass fittings with visual paddle wheel in all PRV discharge piping that goes to a holding tank. Spinning paddle can be used to locate leaking PRV or to adjust spring compression on PRV so that discharge relief pressure is set correctly.

CASE POL 6 - Spring Loaded Check Valve, R. Thomas

Problem: Use of spring loaded check valve as a deadman control valve at truck fill stands when converting from top loading to bottom loading.

Symptom: High surge pressure when spring valve is released and during fueling, overfilled trucks due to "tying open" of loading valve during filling operations.

Collection of Facts: In a top loading configuration, a spring loaded check valve with a pull chain attached was used as the main fuel loading valve. When many top loading fill stands were converted to bottom loading, the spring loaded check valve was reused as a deadman valve. Because of its configuration and ease to wire open, several truck overfills have resulted.

Solution: Replace spring loaded check with hand held electronic type deadman and incorporate "Scully" or similar high level shut-off system.

CASE POL 7 - Latex Lining System for Concrete fuel storage tanks, R. Thomas

Problem: NFGS 09871, latex lining system for concrete fuel storage tanks, requires the latex blend to be used within 45 days of manufacture. For most contracts, this time limitation is too restrictive.

Symptom: Rejection by ROICC of latex paint because its age exceeds 45 days, causing contract delays and reordering problems.

Collection of Facts: The Naval Research Lab has shown that paint as much as 1 year old can still perform good as new if it has been stored at temperatures not less than 40°F nor more than 110°F and that it still has a smooth, paint like consistency.

Solution: Examine the paint for consistency and smoothness rather than date of manufacture. A revision to the specification will be recommended.

CASE POL 8 - Explosive Clearance for Fuel Facilities, R. Thomas

Problem: Apparent conflicts between NAVFAC DM-22 and OP-5 concerning explosive clearances between fuel tanks and buildings, roads and railways.

Symptom: OP-5 (Explosive Safety Manual) clearance requirements far exceeds those required by DM-22 and blindly following them could lead to excessive use of real estate.

Collection of Facts: A discussion with the NAVSEA OPR for the OP-5 manual revealed that the OP-5 clearance requirements are not meant to apply to liquid fuel facilities alone. They are meant to apply to clearances between fuel facilities and buildings that contain explosives or roads and railways that regularly carry munitions and explosives.

Solution: For clearances between POL facilities and ordinary inhabited buildings, public highways, rails, etc. follow DM-22 for requirements.

CASE POL 9 - Flow Control at Direct Fueling Stations, R. Thomas

Problem: It had been observed at several aircraft direct fueling stations that flow control was being provided, with or without pressure control.

Symptom: Providing flow control at aircraft direct fueling stations adds to the cost of the system, increases pressure drop and lengthens fueling time by not allowing the direct fueling station to deliver fuel at its maximum rated capacity.

Collection of Facts: The most important control an aircraft direct fueling station can provide is pressure control. Fuel pressure should not exceed 50 ± 5 psi at the skin of the aircraft. Flow rate into an aircraft is governed by the internal plumbing restrictions and the number of empty tanks fuel is flowing into. The rate which fuel is accepted by an aircraft varies from start to finish, with highest flows occurring initially and a steady decline in fueling rate to zero as the aircraft fills up.

Solution: Design aircraft direct fueling station to provide pressure control and let the aircraft control the rate at which it will accept fuel. This rate will vary from aircraft to aircraft and fueling will be accomplished as fast as possible for each aircraft.

CASE POL 10 - Pressure Control at Direct Fueling Stations, R. Thomas

Problem: Over pressurizing aircraft fuel tanks.

Symptom: Ruptured aircraft fuel tanks.

Collection of Facts: As configured, several Navy and Marine Corps aircraft direct fueling stations cannot limit the pressure at the fueling nozzle to the required 50±5 psi. The provision of a hose-end pressure regulator is only a back-up or secondary device for limiting the pressure to aircraft. The primary pressure control should come from the hydrant fuel control valve.

However, without a venturi, this valve must be set for 50 psi so as not to overpressure the aircraft at no flow conditions. This means that when fuel is flowing, the nozzle pressure may be down to 25 psi or less reducing the flow. If the pressure control valve is set up to 75 psi to compensate for the drop during flow conditions, the plane will see 75 psi at no flow conditions. This is a dangerous situation.

Solution: Install a hose end regulator for secondary protection and provide a venturi controller for the hydrant fuel control valve so that it becomes the primary pressure control valve. With a venturi, both conditions will be satisfied--the aircraft will be protected at no flow conditions, and the control valve will be "tricked" into opening wide during maximum flow conditions.

CASE POL 11 - Pantograph Stops, R. Thomas

Problem: Most existing pantograph stops are made from steel posts with rubber pads. The problem with this is that when pantographs are folded shut, the swivels can clash together, causing damage and leaks.

Collection of Facts: Definitive drawings call for padded posts as pantograph stops. Field surveys revealed that even with pads on pantograph piping, the impact of a folding pantograph causes damage to the swivels.

Solution: A simple yet effective means to prevent pantograph clash and swivel damage was observed at several MCAS's. The idea is to provide stops for the castors before the piping and swivels have a chance to contact each other. Castor stops are shown below and can be provided for as many castors as required.

CASE POL 12 - Static Electricity Relaxation at Direct Fueling Stations, R. Thomas

Problem: Providing static electricity relaxation capability at existing aircraft direct fueling stations while keeping below the 3 foot height limitations.

Symptom: Most static relaxation tanks are of the vertical type, and when used at aircraft direct fueling stations, can cause wing tip damage to aircraft.

Collection of Facts: Older direct aircraft fueling systems and some newly modified systems which have the filtration equipment near the dispensing point are required to provide 30 seconds fuel retention time between the last piece of filtration equipment (the fuel contamination monitor) and the refueling nozzle. In most cases a vertical tank will violate the 3 foot height limitation and there is not room to install a horizontal tank.

Solution: A simple solution, observed at one air station and which saves the approximate $4,000 cost of a non-ferrous relaxation tank, uses little space and provides the required low profile. It is to increase the pipe diameter up to 10" or 12" and to install a large aluminum pipe "U" bend in the piping system. The "U" bend is fabricated from standard elbows or "U" bends and straight pipe and the slower velocity (FT/SEC) times 30 seconds retention time = required length (FT).

CASE POL 13 - Corroded Fuel Tank Bottom, R. Thomas

Problem: Trying to decide whether to replace a corroded fuel tank bottom.

Symptom: 40 year and older fuel tanks with what appears to be a badly corroded and pitted tank bottom with possible leaks.

Collection of Facts: An A/E had decided that the bottoms in several pre-WWII fuel tanks were corroded to the point where the entire bottoms would have to be replaced with new steel. A sight visit and ultrasonic inspection of the bottoms revealed that the bottom plates were made from l/2" steel plate and a hole saw cut indicated that all corrosion was occurring on the inside of the tank and that the underside looked like new steel. Furthermore, corrosion was limited to certain low point areas in the tank. The new tank bottom was to be l/4" steel plate in accordance with latest standards (only l/2 as thick as 97% of the old tank floor).

Solution: Even though some parts of the floor were badly pitted (some pits were as much as 3/l6" deep), there was still more steel left than would be in a brand new floor. All corrosion was interior, therefore, the isolated deep pits were fill welded and new plates were welded over the corroded areas and the edges ground smooth. The entire tank was then coated, producing a tank better than new and at a fraction of the cost.

CASE POL 14 - MIL Specification Fueling Hose, R. Thomas

Problem: Failures with various MIL Specification fueling hoses.

Symptom: Short life, blisters, bulges, cracks and pin holes are just some of the problems experienced with several different MIL specification hoses.

Collection of Facts: For years, the Navy and Air Force have had difficulty in obtaining a good aircraft refueling hose, even though we were buying NIL spec hoses. The problems with the MIL specs seem to be that the manufacturer is being told exactly how to construct his hose and, because of that he cannot take advantage of new advancements in materials and fabrication methods. We have now switched to referencing commercial API hose specifications. These specs are performance oriented versus telling the manufacturer how to construct the hose. The result has been dramatic and we are now getting better fueling hoses.

Solution: Reference API 1529 for aircraft refueling hose, and you will get the performance you want without telling a manufacturer how to construct his hose.

CASE POL 15 - Petroleum Fuels/Energy, R. Thomas

Problem: Incorrect application of the shear-pin type emergency, dry breakaway coupling on aircraft direct fueling pantograph stations.

Symptom: Ruptured aircraft fuel cells if breakaway is attempted with incorrect type of breakaway coupling in place.

Collection of Facts: There are two different types of emergency, dry breakaway couplings used by the Navy in fueling aircraft each with a designated application and they are not interchangeable. The "shear pin" type breakaway is used only on refueler trucks and requires an angle pull for breakaway. The spring loaded detent ball type requires an axial pull for breakaway and is used on pantographs or other swivel type dispensing systems which allow axial pull.

Solution: Insure that the proper type breakaway coupling fits the service application. Otherwise, there may be no protection at all.

CASE M1 - Raceway Tubing for Hyperbaric Complex, T. Hayes

Problem: Thin walled stainless steel tubing used as electrical raceway in hyperbaric facility complex.

Collection of Facts: In an effort to keep carbon steel out of the hyperbaric environment, the contractor installed thin walled stainless steel tubing as electrical raceway. When bends were made in the tubing, it crimped. Cable was pulled anyway causing it to chafe. Rigid steel conduit or EMT should have been installed. Neither creates a hazard in a hyperbaric environment.

Solution: The stainless steel tubing was removed and replaced with rigid metallic conduit.

CASE M2 - Submersible Pump for Fire Protection (Hyperbaric), T. Hayes

Problem: 220 volt submersible fire pump installed in bilge area of hyperbaric chamber complex.

Collection of Facts: As a solution to fire protection requirements, the bilge area of the chamber complex was filled with water, and submersible fire pumps were installed. This was the supply for the deluge system within the chamber. The fire pumps posed a hazard as a shock and fire hazard, and stagnant water pose a health hazard.

Solution: The deluge system should be supplied by a pressurized water tank located outside of the chamber.

CASE M3 - Air of Manned Chambers, T. Hayes

Problem: Large volumes of air are required for ventilating manned hyperbaric facilities.

Collection of Facts: For standard recompression chambers, 48,502 SCF of air is required by the U.S. Diving Manual for ventilation to remove CO_2 and O_2 build-up when the complex is used for the most severe diving requirements. Usually this air is provided by charged high pressure air flask. These flasks themselves are expansive, costly to maintain, and utilize valuable building space. The required number of flasks could be reduced, if the CO_2 and O_2 build-up in the chamber could be reduced. One method to accomplish this reduced build-up would be to pass CO_2 and excess O_2 directly out of the chamber through the inhalator which is provided with an overboard discharge. The Navy has recently approved use of such an inhalator which is manufactured by Scottato.

Solution: Activities having hyperbaric facilities and wishing to reduce air flask procurement and maintenance costs should consider installing the approved overboard discharge systems.

CASE M4 - Oxygen Enriched Testing of Materials, T. Hayes

Problem: Facilities for testing flamability and toxicity of a variety of materials, both atmospheric conditions, and at elevated pressures.

Symptoms: Lack of testing capability

Collection of Facts: There are very few organizations which conduct a flamability test of a variety of materials in 100% oxygen or oxygen at elevated partial pressures. One such organization is NASA at their Clear Lake, Texas laboratory.

Solution: If one desires a certain material to be tested in an oxygen enriched environment, he should contact NASA at (713) 483-5231. Samples of the material will have to be provided and the cost will be approximately $1,000 per sample.

CASE M5 - Drain Plugs for Recompression Chambers, T. Hayes

Problem: Steel drain plugs installed in diver recompression chambers frequently corrode and become frozen in place.

Solution: Use bronze plugs instead of steel.

CASE M6 - Drywall Nails for Hyperbaric Facilities, T. Hayes

Problem: Standard length drywall nails are too long for normal installation of drywall over framing for pocket doors. The exposed nail tip will scar the door when it is slipped into the pocket.

Solution: Use construction adhesive on the framing instead of nails. Nails can be used at the top and bottom plate but not on the framing for the door.

CASE M7 - By-pass for Gas Piping Systems (Hyperbaric), R. Johnston

Problem: Designers often do not plan for by-passes around regulators, dryers, filters and other components of gas piping systems.

Collection of Facts: In the review of many design drawings for hyperbaric facilities, it has been noted that no provisions have been made by designers for by-passes around such piping components as regulators and filters. If these components should fail, there would be no way of providing breathing gas to chamber occupants.

Solution: Provide by-passes around piping components such as regulators and filters.

CASE M8 - Oxygen Dump System, R. Johnston

Problem: Chamber O_2 Overboard Dump Systems lacking differential pressure regulators.

Symptom: Potentially hazardous pressure differential between Bibs mask and outside ambient.

Collection of Facts: Some early O_2 dump systems were installed, in accordance with manufacturers' recommendations, without negative bias differential pressure regulators in the exhaust line. Although no failures have been identified, a failure of the mask vacuum regulator could result in a potentially hazardous suction on the mask due to the pressure difference between the chamber and ambient.

Solution: Install a negative bias differential pressure regulator in all O_2 overboard dump systems and set the differential to approximately 15 psig.

CASE M9 - Materials for Oxygen System, T. Hayes

Problem: Use of Buna-N as seat material for O_2 valve resulted in O_2 fire.

Collection of Facts: Buna-N was used as seating material in an O_2 valve. When the valve was opened, the adiabetic heat of compression caused the Buna-N to ignite resulting in an O_2 fire.

Solution: Do not use Buna-N as seating material in O_2 valves. Use Kel-F or teflon as valve seating material.

CASE M10 - Volume of Ventilation Air - Hyperbaric, T. Hayes

Problem: It is difficult to determine the volume of air actually being used for ventilation of a chamber.

Collection of Facts: The standard procedure is to try to calibrate the exhaust valve using the procedure described in the U.S. Diving Manual.

Solution: Install a flow meter in the exhaust line to determine the exact rate of ventilation.

CASE M11 - Selection of Filters - Breathing Air System, R. Johnston

Problem: Incorrect piping of Pall Trinity particulate filters in breathing air systems.

Symptoms: Excessive pressure drop; premature failure of filter elements.

Collection of Facts: Pall Trinity produces both coalescing type moisture Separator (reverse Ultipor) and particulate filter (Epocel) elements. The housing for these elements is identical, but the direction of flow is opposite for each.

Solution: Correct piping configuration is as follows:

Reverse Ultipor - top inlet/side outlet
Epocel - side inlet/top outlet

CASE M12 - Freeze-up of Dome Pressure Regulators, R. Johnston

Problem: Freeze-up of dome loaded pressure regulators at several facilities.

Symptoms: Icing up of regulators; little or no air flow to low pressure side.

Collection of Facts: At least 2 installations have experienced freeze-up problems. In each case, moisture content of the air was high but within acceptable limits.

Solution:

a. Install 2 regulators in series to "step down" pressure in two stages, or replace regulator with one having higher flow capacity.

b. If possible, replace orifice with one of larger diameter.

c. As a last resort, add a refrigerated air dryer to system.

CASE M13 - Manned Chambers-Pressure Problem (Door), R. Johnston

Problem: The inner doors of some chambers are equipped with dogs. This permits the outer lock to be pressurized higher than the inner lock.

Symptoms: If door dogs fail, inner door may swing open violently.

Collection of Facts: Chamber doors were designed only to withstand pressure from the inside. If subject to a greater outside pressure, i.e. from the outer lock, the dogs could fail causing the door to swing open. This could present a serious personnel hazard.

Solution: Remove dogs from inner lock; in the interim, post sign on chamber to warn against pressurizing outer lock greater than inner lock.

CASE M14 - Air System Drying After Cleaning or Hydro-test, R. Johnston

Problem: Inadequate or time consuming drying of chamber air piping systems.

Symptom: Moisture in system which may lead to corrosion.

Collection of Facts: Various cleaning procedures have been developed which rely on forcing dry, warm air to dry the piping system. Not only is this very time consuming, but water may not be thoroughly removed from recesses or "dead ends" of the system.

Solution: After purging system with air for approximately 4 hours, pull a vacuum on the system for at least 4 hours. A vacuum of 10 inches of water (.73 inches Hg) should be sufficient to boil off any water left in the system.

CASE M15 - Location of Intake for Air Supply, R. Johnston

Problem: Improper location of compressor air intake for chamber air supply system.

Symptom: Carbon monoxide contamination of supply air system.

Collection of Facts: The compressor air intake and filter should ideally be located above the roof outside of the building. In some instances, the intake has been located at ground level in proximity to vehicle exhaust.

Solution: Extend compressor air intake and filter through the roof using a length of PVC pipe appropriately sized. Care should be taken to avoid placing the intake near diesel exhaust stacks, toilet vents, etc.

CASE M16 - Pressurization of Chamber Fire Extinguisher, R. Johnston

Problem: Inadequate pressurization of chamber fire extinguishers.

Symptom: Ineffectual spray pattern in the event that extinguisher is operated at depth.

Collection of Facts: While most chambers are now equipped with gas-pressurized water extinguishers, inspections have indicated that some extinguishers are charged to only 100 psig. Research has shown that a charge of 200 psig is necessary to provide adequate flow when the chamber is at depth.

Solution: Regularly inspect chamber fire extinguisher to ensure that it is charged to 200 psig.

CASE M17 - Hyperbaric Chamber BIB System, R. Johnston

Problem: Potential loss of O_2 breathing capability.

Symptom: No oxygen to chamber BIB system.

Collection of Facts: Some chamber O_2 systems are built with a single in-line regulator. In the event that the regulator fails, there is often no bypass or system redundancy to permit continued O_2 treatment. The only alternative would then be to shift to a less effective Air Treatment Table.

Solution: Design O_2 systems with redundant regulators and valves permitting shifting of O_2 supply from one bank to another, or provide a bypass with needle valve around the regulator.

CASE M18 - Hyperbaric Recompression Chambers, R. Johnston

Problem: Recompression chambers lacking Ground Fault Protectors.

Symptom: Fire or shock due to possibility of electrical spark in the event of line-to-ground fault in the chamber electrical system.

Collection of Facts: Recent inspections have revealed that some chambers lack ground fault protection. Chamber grounding systems may be vulnerable to moisture or other deterioration.

Solution: Require that Ground Fault Circuit interruption be installed on chamber electrical systems.

CASE M19 - Hyperbaric Pressure Relief/Safety Valves, R. Johnston

Problem: Poor location of pressure relief/safety valves.

Symptom: Personnel injury resulting from high pressure air.

Collection of Facts: Pressure relief valves are occasionally installed with their discharge ports inadvertently oriented so that high pressure air may be directed towards operating personnel.

Solution: Exercise care in installation of pressure relief valves. If possible, orient discharge ports away from personnel traffic or provide deflectors to harmlessly direct air away from personnel.

CASE CN1 - Floating Cranes; Free-Fall Restraint, P. Malone

Problem: Dropping a torpedo while transferring from one area to another using a 60 ton floating crane which could have resulted in great loss of lives as well as equipment.

Symptom: While using 60 ton floating crane to off-load torpedoes, the crane operator lost control of the load dropping it onto a barge.

Collection of Facts: Review of the original crane's design revealed that the crane was designed so the load could be lowered in a free fall condition. The operation procedures provided a method to prevent such an occurrence; however, this procedure was not always followed by crane operators. The history of accidents with this model crane indicated that a number of similar accidents had also occurred.

Solution: Design and install modification that prevented the operator from using the free fall capability design of the floating crane.

CASE CN2 - Non-destructive Testing of Crane Hooks, P. Malone and Don Potter

Problem: The requirement for annual disassembly and nondestructive examination of crane hooks was questioned by end users.

Symptom: The end user (Naval Shipyards) felt that it was not a cost effective method of insuring crane safety and that NAVFAC should do something to provide a more cost effective method for accomplishing this requirement.

Collection of Facts: The history of crane accidents was reviewed and it indicated that the only accidents involving hook failure were due to gross over-loads. An engineering investigation project was conducted to study the effect of crack location and fatigue on hook failure.

Solution: The results of the Engineering Investigation indicated that the critical area for hook failure could be examined while the hook was on the crane.

CASE CN3 - Safety Booms for Mobile Cranes, P. Malone

Problem: Failures of mobile crane booms.

Symptom: Mobile crane had a history of failing when an examination revealed only minor damage that on the WW II vintage cranes presented no problems.

Collection of Facts: The review of mobile crane boom design indicates that the new booms were designed using high strength steel (in the 100,000 psi yield range). This high strength steel allowed the l/r ratio support to be increased to maximum ratio. This higher l/r ratio means that if support (diagonals) is lost any where along the boom cord, the l/r ratio will reach critical proportion there by causing boom failure at very low loads.

Solution: Retire booms made of high strength steel from service if secondary members such as diagonals as well as the main cord are damaged.

CASE CN4 - Safety of Slings and Fittings, P. Malone

Problem: Failure of wire rope sling while lifting a rigid load (barge) resulting in damage to the crane and other equipment.

Symptom: While relocating a barge, the wire rope sling broke at an estimated load that was well below the breaking strength of the wire rope.

Collection of Facts: Published breaking strength of the wire rope indicated the wire rope size was correct, the sling was constructed properly, and the sling was maintained in accordance with prescribed procedures, etc. Further investigation revealed that the wire rope was on a fitting that reduced the effective breaking below the safe working level.

Solution: Insure that individuals who have the responsibility for lifts are trained in the limitations of the equipment and the fitting used in any lifting operation.

CASE CN5 - Capacity of Barge Mount Mobile Cranes, P. Malone

Problem: The swing gear broke during normal operation of a mobile crane while operating a barge in moderate sea conditions.

Symptom: Routine preventive maintenance uncovered that the pinion gear of the rotate mechanism had one tooth broken and several other damaged.

Collection of Facts: The mobile crane handbook and other pertinent documents were reviewed. Mobile cranes are designed to operate on level ground and they are not designed to meet AISC or other standards of this type. This means that the normal safety factors of design are not applicable and therefore special precaution must be undertaken when these cranes are employed other than as specified by the manufacturer of the crane.

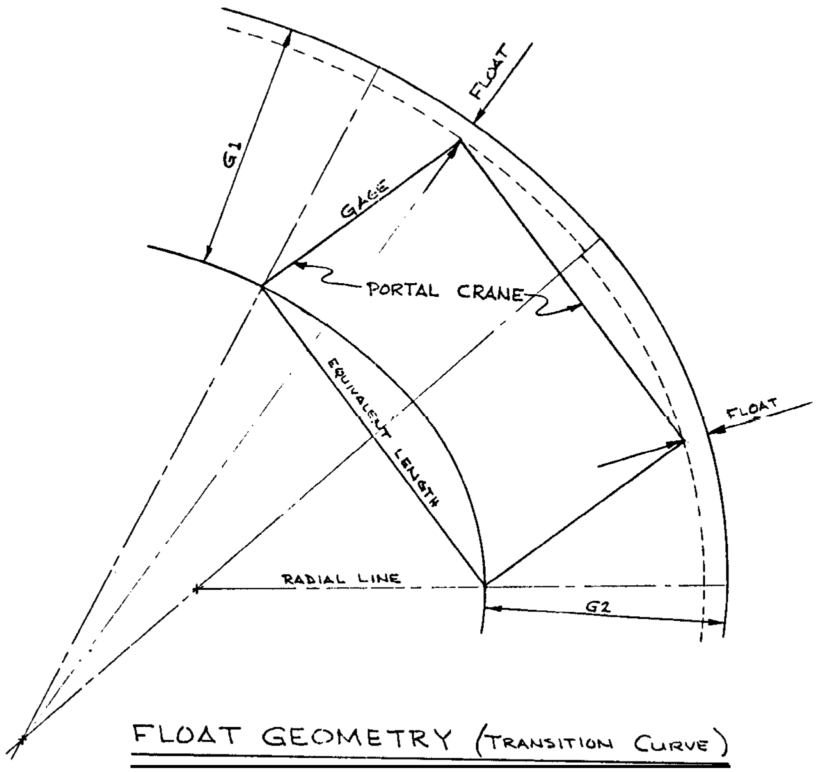
Solution: For mobile cranes mounted on a barge, the capacity chart must be revised to reflect the characteristics of the barge or floating platform on which it is to be mounted. This chart will be different for each type of platform the crane is mounted on and also different for each crane.

CASE CN6 - Float Requirements for Portal Cranes, P. Malone

Problem: Float Requirements for Portal Cranes

Symptom: Portal cranes were experiencing difficulty going around curves. This was evident by the high pitch sound of metal to metal contact as a number of cranes transverse the curves around drydocks.

Collection of Facts: A west coast shipyard proposed that the float that provides a means for cranes to go around curves, designed on portal cranes, should be redesigned so they would operate by the available centrifugal force generated by the crane going around a curve. Float has lateral or sideways movement capability that is built into portal crane running gear. This lateral movement is necessary because the geometry of the rectangular crane frame on a curved track does not allow the corners of the crane to touch both rails (See Figure 1). This phenomenon occurs because the ends of the crane do not fall on a radial line.



FLOAT GEOMETRY (TRANSITION CURVE)

FIGURE 1

If a given crane is operated on a curve of constant radius, the gage can be adjusted so no float is required. However, if cranes of the same gage, but different lengths/wheel configurations, are operated on the same curve, different gage adjustments are required. Therefore, a compromise alignment must be adopted and the difference absorbed by a float mechanism on each crane.

CASE CN7 - Rotate Structures on Portal and Floating Cranes, P. Malone

Problem: Stability of Rotate Structures on Portal and Floating Cranes for handling critical loads.

Symptom: Some of the rollers that provided support under all loading conditions lifted off the supporting structure during load test and evaluations.

Solution: A finite element model of typical portal frame was analyzed. The results of this analysis indicated that the portal frame was flexible and that the rollers carried load in proportion to the stiffness of the supporting member. The rotate structure (upper structure) housed all of the machinery including the power plant. Because of the requirement to maintain alignment of installed equipment, the rotate structure is constructed very rigid and therefore when loaded, does not deflect to the same degree as the portal frame.

Based on the above information and varied field trips a procedure was set up to evaluate existing portal and floating cranes with key points of evaluation as follows:

1. Park the crane on the level section of the track with the boom parallel to the track (this provides the most stable conditions for stability analysis).

2. For NAVFAC designed portal cranes with the 125% test load, check rollers of the least loaded quadrant for contact with the rotate structure and portal frame. If rollers make contact with both structures, stability is satisfactory.

3. If rollers do not make contact with the rotate structure or the portal frame check the center steadment nut for contact with the portal frame. If clearance is maintained between steadment nut and portal frame, stability is satisfactory.

4. If contact is made between center steadment nut and portal frame, an engineering evaluation is required to determine the suitability of the crane for service at the existing rated load.

CASE PS1 - Failure of Barbed Ribbon Tape, J. Cecilio

Problem: Failure of Barbed Ribbon Security Tape

Symptom: Failure-breaking apart of barbed ribbon security tape.

Collection of Facts: Specification MIL-B-52775 general purpose barbed tape obstacle (GPBTO) specified 3 types of material for the manufacture of the tape. Of these, the Navy has been specifying Type III. This allowed the use of 201 and 301 stainless steel. The cold working of the ribbon by crimping the edge to obtain a curve in the plain of the ribbon suffered stress corrosion cracking in these crimps. Fatigue propogated the cracks across the ribbon, causing failure.

Solution: Laboratory evaluation (NRL) showed that 316 stainless steel would perform satisfactorily if manufactured by the same process. The laboratory at Keyport, WA. (NUWFS) showed that proper care in installation would satisfactorily extend the fatigue life.

Specification MIL-B-52775 has been revised adding a Type VI material 316SS for Navy use when exposed to a marine or evergreen acid environment.

CASE PS2 - Vehicle Barriers, J. V. Tyrrell

Problem: Providing adequate vehicle barriers to prevent unauthorized entry.

Symptoms: Unsatisfactory performance, excessive costs.

Collection of Facts: Terrorism and overt unauthorized entry are becoming an increasingly common problem. There are many patented and proprietary systems being offered to capitalize on the sudden demand (5/85).

Solution: In order to design an effective barrier, the size, weight, and speed of the vehicle must be considered. A simple trench or a berm can sometimes be very effective. Heavy blocks (concrete, etc.) or planters can be used. For new facilities, it may be possible to provide a grade separation by means of a low retaining wall along the perimeter to be protected. There is no value in providing an expensive gate control if the adjacent perimeter is not equally resistant.

CASE PS3 - Failure of Barbed Tape Obstacle, J. Cecilio

Problem: Failure of Barbed Tape Obstacle from SWEF PACSUB Base, Bangor

Collection Of Facts: The perimeter fence at the main limited area and remote magazine area approximately 1,800 feet in length. There was over 400 breaks in the barbed tape in the main limited area. All the breaks occurred in the inner coil.

The installation uses a dual coil of 30/24 barbed tape fastened between the "Y" Outriggers on a chain link fence. Breaking and failure of the stainless steel barbed tape fence topping has occurred at several other sites where high winds have been encountered. Corrosion and pitting of the stainless steel has also been observed where the material was installed in a marine atmosphere.

Laboratory analysis has indicated that failure appeared to be caused by fatigue in the defamed areas in the barbed tape. Stress concentration was set up in the deformed area due to crimping and cracks were initiated in this area when the tape was subjected to service load induced by winds, temperature and vibration. In addition, improper installation and fastening of the barbed tape to the fence structures was reported to have caused excessive flexing and movement resulting in acceleration of the fatigue and breakage. The black plastic strapping has also been found to deteriorate and break, which then leads to excessive movement and flexing of the barbed tape under wind conditions.

Solution: Based on the above problem, type specification was modified. Plastic strapping was replaced with steel wire rope. Formalize and provide installation procedures for the barbed tape fence topping. Specify types of stainless steel and manufacturing procedures to insure a more uniform product with better fatigue and corrosion resistance.

CASE A1 - Roofing and Waterproofing, C. B. Key

Problem: Leaking Ammunition Storage Magazines

Collection of Facts: The structures are corrugated steel, sections designed to be constructed at grade level and covered with earth to resist promulgation of exploding adjacent magazines in the event the contents of one or more magazines were exploded. The design was considered to be economically feasible for construction in remote locations. However, they have never been absolutely water tight. It was expected that some rain water would perk through the soil cover and find it's way into the magazines. With the advent of new weapons and missiles that are water and humidity sensitive, it was required that magazines be absolutely water tight.

Solution: A fluid applied elastomeric waterproofing system was applied to the outer surface of the corrugated steel magazines. A protection fabric was placed over the waterproofing membrane to preclude damage to the membrane. A six inch thick aggregate drainage course was placed over the protection fabric. This allowed water to drain down each side of the barrel shaped structure and be collected by drain tiles parallel to each side of the structure. The drain tiles carried the water out through the head wall to a storm drain.

CASE A2 - Roofing and Waterproofing, C. B. Key

Problems: Slippage of built-up roofing

Collection of Facts: A built-up roofing membrane show signs of slippage. This was evident by the appearance of breaks in the aggregate surfacing parallel to the felts. Slippage is caused by using a type of bitumen having a softening point too low for the slope of the roof on which it is used. This roofing membrane was installed over roof insulation as are 90% of all built-up roofs. Since the slope did not exceed one inch per foot, wood nailers for backnailing the felts were not provided.

Solution: Aggregate was removed in lines approximately sixteen inches wide, eight feet apart, parallel to the slope of the roof. Nails were driven through the roofing felts approximately twelve inches on center down the center of each line where aggregate had been removed. Stripping felts four inches and twelve inches respectively were installed in bitumen over the nails up each line. Bare areas were then flood coated with hot bitumen and aggregate embedded. The nails served as shear pins and stopped the slippage of the felts.

CASE A3 - Roofing and Waterproofing, C. B. Key

Problem: Alligatoring of aluminum pigmented asphaltic roof coating

Collection of Facts: Within three months after an aluminum pigmented asphaltic coating was applied on a smooth surfaced built-up roof, it began alligatoring. This was a new built-up roof. A glaze coat of asphalt had been applied to the surface of the built-up roof as a temporary protection of the felts during construction. The glaze coat of asphalt had not been left exposed to the weather long enough to oxidize and still possess cold flow properties. This is what caused the alligatoring in the aluminum pigmented asphaltic coating.

Solution: The roof coating was allowed to continue alligatoring for approximately six months, at which time the alligatoring stopped. This is because the asphalt was allowed to oxidize. The roof was recoated with aluminum pigmented asphaltic coating and there were no subsequent problems.

CASE A4 - Roofing and Waterproofing, C. B. Key

Problem: Wind blown aggregate surfacing on built-up roofing

Collection of Facts: Wind blown aggregate on built-up roofing in Guam caused damage to automobiles and other structures during typhoons. Membrane felts were left bare and unprotected from ultraviolet rays of the sun which deteriorate the felts.

Solution: Double aggregate surfacing was used. The gravel was coated with a fine spray of kerosene to improve adhesion. The aggregate was applied in two layers. The first layer consisted of four hundred pounds of gravel embedded in sixty pounds of hot asphalt per one hundred square feet. The second layer consisted of three hundred pounds of gravel embedded in eighty pounds of hot asphalt per one hundred square feet. All loose gravel was removed.

CASE A5 - Roofing and Waterproofing, C. B. Key

Problem: Poor adhesion and blistering of built-up roofing on high moisture content decks.

Collection of Facts: When built-up roofing is hot-mopped to high moisture content decks, e.g., gypsum, lightweight insulating concrete, the roofing system resulted in poor adhesion to the deck and often resulted in blistering.

Solution: Mechanical fastening of an inorganic base sheet or vented base sheet was found to eliminate this problem. Subsequent plies of roofing felt were hot-mopped to the base sheet.

CASE A6 - Roofing and Waterproofing, C. B. Key

Problem: Blistering of built-up roofing when applied over polyurethane roof insulation.

Collection of Facts: In the latter seventies, many built-up roofs applied over polyurethane insulation were noted to produce blisters at the interface between the insulation and the first layer of felt. The blistering was believed to be caused by moisture in the facing felt of the insulation or offgasing of the polyurethane insulation. None of these theories were ever proven.

Solution: This problem is eliminated by placing a thin layer of fiberous glass, perlite board, or mineral fiber board insulation between the polyurethane insulation and the first layer of roofing felt. It is purely academic to prove whether the cause of blistering is offgasing or moisture vapor. However, a porous insulation, in contrast to a closed cell insulation like polyurethane, allows any gaseous or vapor pressures to dissipate laterally and reduce the concentrated effect that caused the blistering.

CASE A7 - Roofing and Waterproofing, C. B. Key

Problem: Determining the correct temperature for heating asphalt used in built-up roofing.

Collection of Facts: Until the oil embargo in the early seventies, imperial temperatures specified in ASTM D-312 were satisfactory for heating asphalt for use in built-up roofing without producing any adverse effects. However, when we began acquiring oil from different sources, the asphalt derived from these crudes produced unreliable characteristics when heated in accordance with these imperial temperatures. This often resulted in lowering the softening point of the asphalt because it was heated above the actual temperature required. The results were that the asphalt and roofing membrane would slide down the roof. Some asphalts also required hotter temperatures than recommended in ASTM D-312 to obtain proper adhesion.

Solution: It was determined in the roofing industry that a more reliable method of obtaining the right temperature at which asphalt should be heated for proper application was based on viscosity. The concept of Equiviscous Temperature (EVT) has replaced the use of imperial temperatures in the roofing industry. The EVT is the temperature at which the viscosity is 125 centistokes when tested in accordance with the requirements of ASTM D-2170. The proper temperature for application of asphalt is a range between twenty-five degrees Fahrenheit above the EVT and twenty-five degrees Fahrenheit below the EVT. Asphalt manufacturers' labels or bill of lading are now required to provide the EVT.

CASE A8 - Roofing and Waterproofing, C. B. Key

Problem: Retarders for roofing.

Collection of Facts: Vapor drive is always from hot to cold. A vapor retarder should not be used in a roof assembly unless it is necessary. If moisture is trapped between a vapor retarder and the roofing membrane, it could cause blistering of the membrane, delamination of the felt plies, and premature roof failure. If a vapor retarder is needed and not used, the vapor drive could force moisture into the insulation reducing the "R" value of the insulation and if organic felts are used, moisture can be wicked into the felt plies. This could result in early roof failure.

Solution: Only use a vapor retarder when the average January temperature is 40 degrees Fahrenheit or below, and the inside relative humidity is 45% or higher. Never use a vapor retarder in a roof assembly over a cold storage facility.

CASE A9 - Roofing and Waterproofing, C. B. Key

Problem: Lack of information on roofing materials used on construction.

Collection of Facts: Roof maintenance personnel, inspectors, consultants, and contractors performing work on roofs after original construction need to know what types of materials the roofs are constructed of, to assure use of compatible materials. If the wrong materials are used, it could cause damage to the roofing. The contract specifications require that the Contractor provide an information card near the roof access describing the types of materials used in the roof construction. However, this is not being enforced, e.g., roofing inspections at TRIDENT Base, Kings Bay revealed that not one building inspected had the required information posted.

Solution: Enforce the requirements of the contract. Make this a standard item on the ROICC punch list.

CASE A10 - Roofing and Waterproofing, C. B. Key

Problem: Interior roof drain problems.

Collection of Facts: Leaks through the ceiling that are often thought to be roof leaks are frequently caused by leaks from roof drain piping above the ceiling. In cold climates, interior roof drain piping systems provide thermal bridging in the building envelop which allows warm humid air to condensate on the cold surface of the drain pipe system, causing moisture problems within the building. The effects of this phenomena are often confused with that of a roof leak. An attempt to rout-out roof drain piping above the ceiling may cause additional leaks due to vibration as these pipes are supported by pipe hangers. Occasionally ceilings, walls and floor slabs have to be removed to provide accessibility to the roof drain piping system to make repairs. Interior roof drain piping systems are more expensive to install and maintain than perimeter roof drain systems.

Solution: Perimeter roof drain systems are preferred. As a general rule, all buildings having a width of 100 feet or less should use perimeter roof drains. For buildings that use interior roof drains, consideration should be given to provide the following:

- o Accessibility for future maintenance.
- o In cold climates insulating roof drain piping above the ceiling.
- o Securing of roof drain piping above the ceiling adequately to prevent leaks caused by vibration during routing-out.

CASE All - Roofing and Waterproofing, C. B. Key

Problem: Roofing Flashing Failures.

Collection of Facts: Experience has shown that the majority of leaks in roofing systems occur at flashings. If the problem is not detected and repaired soon enough, it could result in serious and costly damage to the roof assembly, building structure, and interior finishes and contents. The inconvenience and frustrations of building users are transformed into low morale and lost productivity of the organization. Although the roofing generally represents only 2% of the total building cost, over 50% of all design and construction contract litigation results from roofing problems. There is nothing more embarrassing to a designer, contractor, or building owner than to have a roof leak in what otherwise appears to be a well designed and constructed building, representing a tremendous capital investment. Then there is repair or replacement cost for the roofing system and related damages. The cost of roofing replacement alone can run from $250 to $500 a square (100 sq.ft.) depending on the type of roofing and complexity of the job. The Lessons Learned are that flashings fail generally for one of two reasons: (1) failure to incorporate provisions to accommodate differential movement resulting from thermal expansion and contraction or deflection; and (2) failure to incorporate the most maintenance free design concepts. Preventative maintenance is very seldom accomplished and is generally only provided in a crisis when the roof leak is visible and disturbing within the building.

Solution: It is the design philosophy of the Naval Facilities Engineering Command to incorporate features in flashing details that will accommodate differential movement and provide the most maintenance free design concepts. Specific examples are provided as follows:

a. Minimize the number of penetrations through the roof by grouping pipes and conduits into fewer strategic locations. See attachment 1.

b. Assure that penetrations do not occur at low points of the roof.

c. Do not use pitch pockets. See attachments 2 and 3. Pitch pockets require frequent inspection and maintenance to maintain a waterproof seal. Use flashing collars with umbrella flashings. See attachment 4.

d. Do not use surface applied cap flashings. See attachment 5. Surface applied cap flashings have a high rate of failure. Install all cap flashings in reglets raked in masonry or cut or cast into concrete. See attachment 6.

e. Locate vent, stacks and other individual penetrations through the roof not less than 18 inches apart, and from walls and other vertical surfaces. See attachment 7. Flashings for vent stacks should be as illustrated in attachment 8.

f. Use perimeter roof drains in lieu of interior roof drains when possible. See attachment 9. If interior roof drains are absolutely necessary, provide a means of expansion between roof drains and leaders to allow the roof drain to move with the roof assembly when subjected to allowable deflection. When this movement is restricted, it can break flashing connections between the roof drain and roofing membrane, allowing water to enter.

g. Elevate metal roof edges to keep metal work above the water line. See attachments 10 and 11. Do not strip flash metal items longer than 2 feet into the roofing membrane. See attachment 12.

h. Install roofing expansion joint covers above the water line. See attachments 13 and 14.

i. Where there is potential for deflection of the roof assembly at abutting non-supporting walls and penetrations, design flashings to allow for differential vertical movement. See attachments 15, 16 and 17.

CASE CC1 - Failure of Wall, M. Yachnis

Project: Rotating Arm and Maneuvering Basin at the David Taylor Research and Development Center, Carderock, Maryland. The structure consists of heavily reinforced concrete walls and floor slabs. The rotating arm is round while the maneuvering basin, which is connected to the rotating arm, is rectangular.

Problem: Failure of the rotating arm wall.

Symptoms: The structure under discussion is shown in Fig. 5. During the placement of concrete on the inside face of the wall and at elevations between 128'-0" and 131'-9", the forms failed outwards for a length of approximately 20 feet.

Collection of Facts: The experts review of the collapse concluded that the contractor had selected forms based on experience and intuition rather than on structural computations. The concrete was completely disintegrated and the reinforcing steel misplaced. The cost of replacement of the damaged part of the wall was approximately $500K.

Solution: Forms are very important elements of a structural system. As such, they must be analyzed and designed appropriately to withstand to predetermined loads and carry the stresses given by various codes. Therefore, they must be approved by a professional engineer as the rest of the structural system.

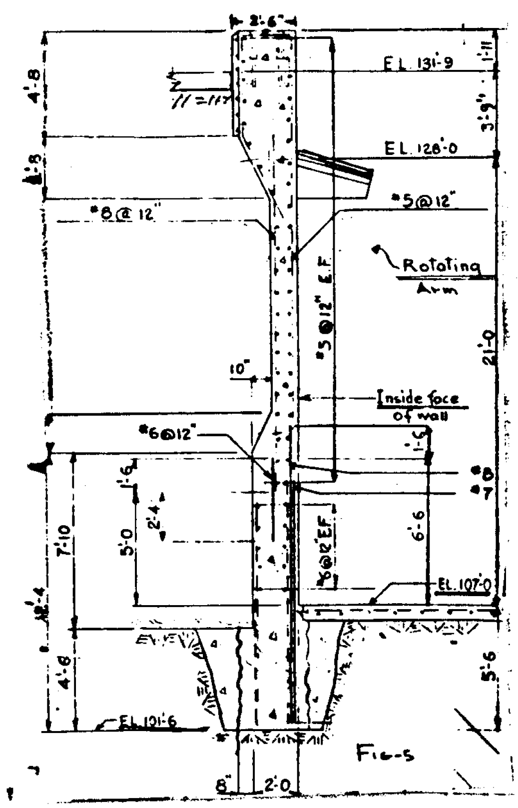


Fig-5

CASE CC2 - Contractual Dispute-Light Pole, M. Yachnis

Problem: Contractual dispute on flood lighting pole section at Naval Academy, Annapolis, Maryland.

Symptoms: Aggravation.

Collection of Facts: Specification calls for a tubular section for a flood lighting pole. Drawings were shown a tubular pipe section. Contractor provided an octagonal section which met the specifications.

Solution: Be careful that there is a complete agreement between plans and specifications.

CASE CC3 - Substitution for Design Requirements, J. V. Tyrrell

Problem: Improper substitution for design requirements.

Collection of Facts: This problem is one that is continually repeated when field personnel approve substitutions without first checking with the designer. One instance involved a 1.5 million gallon water sphere indicated at the Naval Oceangraphic Research Station, Lewis, Del. The design gave approximate dimensions and specified the section modulus and moment of inertia of the stem. A manufacturer proposed a substitution using a smaller diameter stem which provided a section modulus very close to that specified but a moment of inertia considerably less. The substitution was accepted by the ROICC. The construction was substantially completed and the system was being tested when a hurricane passed close to the activity. When the main force of the stem was about 1 hour from the activity, the ROICC called to report that the sphere was swaying as much as 15 feet and wanted to know if he should attempt to empty it. He was told to clear the area and hope for the best. Fortunately, the structure survived and has been in operation for over 20 years.

Solution: Many cases do not have a happy ending like the one cited. Field personnel should not approve any substantial changes in design without consulting the designer. Often it is not apparent that the chance is "substantial", therefore it is advisable to contact the designer about change whenever possible. For a MCON project, the contact should be with the EIC at the NAVFAC Engineering Field Division.

CASE CC4 - Acceptance of Off-the-Shelf Structures, J. V. Tyrrell

Problem: Acceptance of structures not designed for the site.

Symptoms: Structural distress; change orders; increases in contract cost.

Collection of Facts: Sometimes off-the-shelf items will provide the most economical solution to a design problem. Some of these items are actually pre-engineered but not stockpiled in great quantities and instead fabricated when ordered. For this type of structure, manufacturer's data is usually available showing what loadings were considered in design. If the design loading is not carefully checked against the intended use and the prevailing site conditions, the structure may prove unsatisfactory.

The need for verifying the design may seem self-evident, but we have many cases where inadequate structures were acquired or contracted for before the inadequacies were discovered. Apparently there is some inclination to accept whatever is commercially available without carefully considering the requirement.

Solution: When using off-the-shelf or pre-engineered structures, check them for the loadings intended including environmental loadings at the site (wind, snow, earthquake, soil conditions, etc.). If the structure is not adequate, do not use it unless the manufacturer modifies it or you expect to reinforce it separately. The cost of modification should be included in the project.

CASE CC5 - Erection of Cantilever Hangar, J. V. Tyrrell

Problem: Collapse during erection.

Collection of Facts: A typical cantilever type hangar with tension strut suspender was being erected, at NAS Miramar, using scaffolding and jacks to position the cantilever ends at the correct elevation before connecting the suspender. This process had apparently been successfully used previously. In this case, one of the trusses slipped off of the jack creating a domino collapse and resulting in injury to personnel. Several causes were possible. This method inherently involves lateral forces when two adjacent trusses are jacked to different elevations. The scaffolding is designed to minimize weight and has little reserve strength. It was not capable of sustaining the truss when it toppled and, consequently, massive collapse followed.

Solution: This method of erection is not recommended. Instead, it is suggested that the tension suspenders be connected immediately with a provision for adjustment in the splice. The trusses can then be jacked to proper elevation without the possibility of dropping the structure. Erection methods are usually the contractor's domain; however, at a minimum, any contractor should be made aware of the potential difficulties and at least be required to submit a detailed plan and sequence for approval. If jacking is attempted before connection of the suspenders, the scaffolding should be carefully checked, provision should be made to brace the scaffolding and the jacks, and the maximum difference in elevation permitted should be established by structural calculations.

CASE CC6 - Tower Base Plate, E. Mifflin

Problem: Excessive machining.

Symptom: A base plate in an insulator replacement assembly was found to be inadequate.

Collection of Facts: Another plate of much better strength was procured by a government official. This higher strength plate was one (1) inch thicker than the original, so the procurer specified the plate be machined to the thinner thickness. Had the official and/or his agent consulted with the engineer who discovered the original deficiency, the extra machining could have been omitted. The extra machining at least tripled the cost of the material.

Solution: Keep the technical people informed. They may be able to help save some money.

CASE CC7 - Specification Definition for Fill, A. H. Wu

Problem: Interpretation of 4 inches of "porous fill" to be installed under a 5 inches concrete slab. Contractor interpreted the porous fill as being a borrow sand or clean sand in his bid, and he is claiming $8,600 for a change order for using concrete sand as porous fill as directed by the ROICC.

Collection of Facts: The spec did not specify the requirement for "porous fill." However, the legend and symbol used in contract drawings indicate the porous fill is coarse gravel.

ASTM C 33 No. 57 size material should have been defined as "concrete gravel", not "concrete sand". This was an error in the specification. The barrow material (SM or SC) which the contractor planned to use as compacted fill was also planned for use as porous fill. Such a deviation is not permissible because it would not comply with the requirements on the contract drawings.

Solution: The porous fill should be interpreted as gravel material, and specified as such, with the size ranging from l/4" to 2-l/2" or other similar material selected by the designer. Be careful in specifying porous fill. ROICC's should check with design EIC when interpreting contract requirements.

CASE CC8 - Sewer Pipes, A. H. Wu

Problem: There was a contract dispute regarding requirements for a storm drain placed at the Anacostia Naval Station. The contractor argues that water was not a problem at the Anacostia jobsite.

Symptoms: The contractor contends that the specification requirement for a dewatering system is to prevent the sides and surface of the excavation from becoming soft. Since this did not happen, he felt he had fulfilled the intent of the contract. Furthermore, the contractor contended that the requirement to remove water to one foot below the trench floor is unrealistic since the soil is clay-like and impervious. The contractor argued that the conditions in the trench bottom were abnormally soft, not due to water content, and that a change order and direction from the government were required to allow him to proceed. The contractor stated that the contract requires him to use excavated material for backfill. The contract does not state that he must treat or dry the soil in any special way. Therefore, he is not responsible if compaction requirements are not met and if the pipe is bowed and misaligned. The contractor felt he has performed his work in fulfillment of the intent of the contract and since the work is unsatisfactory to the Government, a change order should be executed for time and money for him to proceed.

Collection of Facts: The Government's position was that the contractor has not fulfilled the requirements of the contract and has not fulfilled the intent of the contract by not producing useable, satisfactory work. The contract states that a dewatering system is to be in place and operating before excavation. This has not happened. The Government felt that a dewatering system before excavation would render the excavated material suitable for backfill and allow it to meet compaction requirements. A dewatering plan would affect the softness of the trench floor, and in conjunction with excavation methods described in the contract, will provide a more stable bed for the pipeline and reduce the additional gravel bed the contractor claims is required. The contractor has not excavated the trench in conformance with the contract specifications.

Solution: Fill the open trench area as soon as possible and provide flood protection from the river. Leaving the trench open was viewed as a safety hazard endangering the lives of personnel working on the base, as well as a potential risk to property.

The contractor was directed several times to fulfill the requirements of the contract. He has been reminded that the contract does not specify that he must use a wellpoint system and that the selection of another system is his choice as long as the dewatering and compaction requirements are met. To the time of this writing, the matter has not been resolved.

It is felt that the specification was clear and adequate. Therefore, the Government may initiate default proceedings for non-performance. All requirements and provisions of Clause 5 of the General Provisions should be followed.

CASE CC9 - Failure of the Outlooker-Handrail System, M. Yachnis

Problem: Failure of the Outlooker-Handrail System, on BEQ at Henderson Hall

Symptoms: Cracks in concrete in the area of the anchoring studs.

Collection of Facts: At 2:00 p.m. on August 24, 1981, the connections between the balcony cantilever beams - outlookers - and the concrete handrails failed catastrophically causing the third floor handrails on the outside balcony of the south building (Fig. 20) to fall on the handrails of the second floor which in turn fell on the ground. Ten of the outlookers totally failed and fifteen others suffered damage of various magnitude.

An engineering investigation, which included destructive and non-destructive testing, was performed.

The Bachelor Enlisted Men Quarters at Henderson Hall consist of a two level parking garage and a multi-story barracks and dining facility. The configuration of the total structure is such that the North Building and South Building enclose a central plaza which is located directly above the garage.

The structural framing of the garage consists of a reinforced concrete slab, beam and column system. The barracks structural system consists of precast prestressed concrete hollow core planks supported on bearing concrete masonry unit walls. Cantilevered beams (out lookers) support the balcony slabs. These beams were poured integrally with the exterior columns. Precast concrete panels 5'-9" high and with thickness varying from 4" to 6 l/2" constitute the handrails which are supported by the outlookers. The handrails are connected to the outlookers by two steel angles welded to plates which are anchored to both the handrails and outlookers by steel studs.

An extensive test program was initiated which included:

1. Destructive Testing

Concrete cores were taken from the damaged beams and were subjected to compressive tests. The dimensions of the cores are as follows: Diameter: 3.7"; Height 7.4"; Area: 10.75 sq. inches. It was found that the T-day compressive strength was approximately 4,600 psi which exceeded the design stress of 4,000 psi. The steel of #3 stirrups was tested with results exceeding 100,000 psi.

2. Non-Destructive Testing

Compressive strength tests were performed on the structural members by using the rebound (Swiss) hammer. The average compressive strength was approximately equal to 4,000 psi. Core tests, however, demonstrated compressive strength greater than 4,000 psi.

The outlookers were measured to be 2 5/8" longer than the construction drawings required. Even though this increase in length of the outlookers results in overstressing of the tensile reinforcement, it is not related to the subject failure.

The exact location of the stirrups in the outlookers was found by using a reinforcement locator (Magnetometer). Some of the stirrups were not located in accordance with the construction drawings. However, this condition did not reduce the loading capacity of the outlookers.

The welds at the connections between the outlookers and the handrails were visually inspected. Magnetic Particle Inspection (MT) or Dye Penetrant Inspection (PT) were recommended for some suspect welds.

Computations demonstrated that the tensile reinforcement is slightly overstressed while the web reinforcement does not meet the applicable ACI Code. The Code allows a waiver under the condition of performing a strength evaluation (Load Test).

3. Test Loading

The test loading was performed in accordance with part 6, Chapter 20 "Strength Evaluation of Existing Structures" of the American Concrete Institute Building Code (ACI 318-77). At section 20.4.3, the Code states "That portion of the structure selected for loading shall be subject to a total load, including dead loads already acting, equivalent to 0.85 (1.4 D + 1.7 L) where D = Dead Load and L = Live Load.

(1) Method of Loading

Falsework was used for safety precautions (Fig. 21). A schematic of the method of loading is shown in Fig. 22 and the various increments in Fig. 23. Deflections were measured by using deflection gages capable of measuring from .001" to 1.0". The deflection measurements are as follows:

Increment	Deflection in Inches
1	.0012
2	.003
3	.0036
Full Load	.084
After 36 Hours	.0996
Unloaded	.0072

Total predicted deflection was .095" which was greater than the deflection under full load. Creep was observed 36 hours after completion of testing. The deflection differential was 0.0156" within accepted limits. Almost full recovery of the outlooker demonstrated that no yield occurred in the main tensile reinforcement. Visual inspection showed no shear cracks or diagonal tension cracks during testing. Few hairline cracks in the tension area appeared during maximum loading which were closed totally during the rebound period.

Solution:

1. Anchoring Studs.

Symptom: The separation of anchoring studs from the concrete shown in Enclosure 2 is evidence of lack of sufficient embedment or concrete cover.

Remedy: Provide additional embedment and concrete cover.

2. Bars at the end of outlooker (Nose Bars).

Symptom: Lack of nose bars.

Remedy: Add nose bars.

3. Beams which will not be restored.

Symptom: Hairy shear cracks.

Remedy: Seal cracks with mortar to prevent moisture and corrosion of steel.

4. Reinforcing Steel.

Symptom: Small cracks may be evidence that stirrups and tensile steel may be inadequate.

Remedy: Perform a load test on an outlooker and measure deflections. If load test demonstrates inadequacy of the outlooker, increase the strength by appropriate methods.

Based on the test results, it was determined that the outlooker was adequate to carry the design load. It is noted that the outlooker-handrail system is anchored without any allowance for expansion and contraction. It is predicted that during periods of large temperature differentials, expansion cracks will appear. For this reason, it is strongly recommended that a monitoring system be instituted which will report unusual movements and subsequent cracks.

CASE MA1 - Shipyard Items Requiring Maintenance, T. Hayes

Problem: Maintenance of equipment at most Naval shipyards is poor.

Collection of Facts: Very little effort has been devoted by shipyards to maintenance of equipment. At almost every shipyard visited, especially in the area of drydocks, there is blatant evidence of neglect of equipment. Utility lines are excessively corroded, capstan pits are filled with water packing glands on valves and pump leak, valves and pumps are excessively corroded, flange bolts and nuts are excessively corroded, pumps are in need of overhaul, electric motors need to be rewound, and manned spaces are in need of general house cleaning. Valve stems are either broken or missing from utility outlet stations, electrical conduit is excessively corroded, cover plates are missing from junction boxes, doors to weather proof electrical equipment are opened or missing, large chunks of concrete ark hanging loose on-drydock walls, atlas, galleries or coping. These items are not included in the drydock safety certification program because they do not directly affect the safety of ships in the drydock. However, neglect of these items results in hazards to personnel or in costly replacements. In many cases, the shipyards have a preventative maintenance program. However, care for the aforementioned items are not included in the program. The program for the most part includes greasing or changing of oil for mechanical equipment.

Solution: The shipyards should provide more effort to the upkeep of equipment in the drydock area.

CASE MA2 - Maintenance for Roofs, C. B. Key

Problem: Roof failure due to lack of maintenance.

Collection of Facts: Many roofs fail prematurely due to lack of maintenance, "out of sight, out of mind until they leak". Field investigations of roofing at TRIDENT Base Bangor in June of 1984 revealed many roofs in need of maintenance, e.g., punctured base flashings, erosion of aggregate surfacing, roof drain sumps filled with debris. These things start out as minor problems but, left unattended, result in major roof problems.

Solution: More frequent routine maintenance by qualified maintenance personnel. Each roof should be inspected not less than twice a year by personnel equipped to perform the necessary routine maintenance during the inspection. Maintenance that will require more planning and preparation should be accomplished as soon as possible.

PAINTS AND COATINGS

CASE PS1 - Floor Paint, P. Malone

Problem: Poor performance of a product recommended by a salesman.

Symptom: Life of the special floor paint was well below that promised by the product salesman.

Collection of Facts: The floor paint was applied in accordance with the instruction provided by the manufacturer. The salesman's classic comment was, "I did not know you were going to use it in that shop area," although he personally toured the area when the recommendation was made.

Solution: Use no new product until proof of performance has been established.

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