# Construction of Port and Facilities on Horn of Africa—Lessons Learned

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**Abstract:** Due to the increasing strategic importance of the African continent, there has been an increase in demand for ports and port facilities along its coastline. Sea trade to and from ports all over the world tends to make the Horn of Africa a focal point for waterborne traffic of the world. The assurance of the highest possible quality per dollar spent on port construction is of utmost importance to the host country (owner). Use of the principles and insights, which were learned during performance of quality assurance function on port construction project in Somalia and are shared herein, will maximize the probability that the quality of work produced is that which was designed. Proven-in-action success techniques related to production are divulged which will help the contractor realize expeditious, economical field operations and solve construction problems before they occur by preparing himself in advance to deal with them.

## Introduction

Due to the high cost of the port construction and its vital importance to regional development, the assurance of the highest possible quality per dollar spent is of great interest to the owner. A port is needed that will last a long time without costly repairs and maintenance and for which the design benefits of optimal discharge and receipt of cargo and passengers will be achieved. Port projects which are plagued with construction-related problems reduce these benefits. Such problems also reduce the contractor's profit margin. In addition, time delays and poor quality which result from construction-related problems thwart the very development that the port was intended to promote.

The primary subject to be addressed is quality assurance. The theme of this paper is to show the U.S. Government's first approach to assure quality, within the context of a case history of construction of a port and facilities at Berbera, Somalia, to show the aggressive action that was finally necessitated to make the contractor quality control system work in the unique physical and cultural environment of Somalia, and to document the lessons learned. As a general rule the four major objectives of the buyer of a port and port facilities are quality, time, money, and safety. This means safely finishing the port and facilities with the quality specified and on time, without exceeding the agreed sum of money for completion of the contract. In protecting the interests of the owner, the main objective of highest priority (exclusive of safety) that the resident engineer and his staff were most concerned with on the project at Berbera was quality. They were to assure the finishing of the project with the specified quality. The resident engineer office began with the resident engineer, supervisory civil engineer (the writer of this paper), and an engineer officer; when construction began in earnest, two quality assurance personnel were added. As the resident engineer had

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political and contract administration duties at another project at Mogadishu (capital of Somalia) that kept him away from Berbera much of the time, he delegated duties to the supervisory civil engineer including the responsibility of administering and implementing a quality assurance program at Berbera. In the construction of ports and facilities at Berbera where the product was built in place and took less than two years to construct, the U.S. Government (as the owner's agent) had the fortunate opportunity of being able to look over the shoulder of the contractor from the beginning of mobilization to contract completion. Many principles and insights related to the assurance of quality were learned during the performance of quality assurance functions on this construction project. Other insights, which were learned by the writer during the performance of quality assurance functions on related construction projects in the Azores and South Korea, were applicable to this project. Use of the principles and insights related to quality assurance, that are shared herein, will maximize the probability that the quality of work produced is that which was designed and will help ensure that the project is completed on time without exceeding the agreed sum of money for completion of the contract.

Although the theme of quality assurance remains throughout the primary focus of interest, an effort was made to explore an interrelated subsidiary topic. In this unusually harsh physical environment, success techniques were learned which facilitated coping with the harsh environment and getting the construction job done in the context of the Somali culture. Thus, the second area addressed in this paper is proven-in-action success techniques, related to production on the Horn of Africa, that will help the contractor achieve high-quality workmanship, realize expeditious, economical field operations, and maximize his profit margin.

Exclusive of safety the three major objectives of a contactor are generally economy, quality and time. Considering the realities of today's construction industry in the context of the economic marketplace, economy (maximizing profit) must have high priority for the corporation to survive. Sometimes contractors do not get the project completed within cost requirements because they do not know how to economically produce in the environment of the Horn of Africa. A lesson of paramount importance learned by all those involved in construction in Somalia was that the physical environment of the Horn of Africa requires unique consideration in construction. This environment presents critical construction problems related to dust, sand abrasion, high solar radiation, temperature extremes, soil conditions, water quality, corrosive environment, tremendous wind velocities during monsoon season, unavaibility of construction equipment and materials in the host country, high attrition rates among skilled workers, and constant breakdown of equipment. During the kharif (hot wind of the monsoon season) work could not proceed on some days due to high wind velocities. There were many turning points in the course of construction in Somalia where obstacles and delays occurred and proved costly. Problems encountered during construction of the port are documented. Valuable lessons gleaned from this experience, from experiences in the Azores and South Korea, and an additional two years' experience of working with top engineers and inspectors while performing the quality control function on previous construction projects in Mogadishu, Somalia, from 1966 to 1968 are revealed. The success techniques that are divulged will enable a contractor working on the Horn of Africa to solve many, if not most, of the construction problems before they occur by preparing himself in advance to deal with them. This will facilitate his improving economy of construction and finishing the project on time with the quality specified.

## Scope of Work

In 1983 a construction contract was awarded for enlargement of the port and facilities at Berbera, Somalia. The scope of work entailed an addition of a 330-m quaywall to an existing 300-m quaywall and construction of a causeway, small boat wharves, petroleum fuel facility, navigation aids, moorings, transit shed, latrines, pile-supported offshore structure, preengineered buildings, and utilities. The face of the quaywall was designed as an anchored bulkhead system consisting of steel sheet piles and king piles (steel H-piles welded to sheet piles). The quay fill was specified to be noncohesive material, and the cores of the causeway and two dikes were to be constructed of a residuum from quarry operations. Over 100,000 tons of rock would have to be blasted and placed in the dikes and causeway. The owner of the completed port and facilities was to be the Somali government, and the Naval Facilities Engineering Command was financier and acted as the owner's agent.

## Environmental Perspective

Somalia is a country slightly smaller than Texas, of approximately 6,400,000 people, that is located on the Horn of Africa. Berbera, Somalia, is one of the hottest places on earth. The mean annual rainfall is 2 in. During the hot season, the temperature exceeds 130° F and never dips below 100° F at night. The landing strip and the town are exclusively surrounded by barren desert. Arriving in Berbera can be physically shocking due to the 130° F temperature and the kharif (the hot wind of the monsoon season) blowing across the Gulf of Aden from Arabia. The first contingent of Americans (eight contractor personnel, the writer, and an engineer officer) lived in a house on the local economy. There were significant health problems for Occidentals. Being ill and working in the hot sun in temperatures exceeding 130° F was mentally and physically demanding. After moving into air-conditioned trailers in the labor camp in late August, personal survival became easier.

## Development of Port Prior to 1983

Berbera is an ancient port on the Gulf of Aden which first appeared in the record of Arab geographers in the thirteenth century. In 1869 Egypt occupied Berbera and improved the port by constructing piers and lighthouses. The British occupied Berbera in 1884 and by 1959, just before their departure, developed Berbera Harbor and completed construction of a pier and navigation aids. In 1960 the British cut their colonial ties with British Somaliland, and Russian engineers examined the possibilities of improving harbor facilities. Construction of a 300-m quaywall, animal causeway, and transit shed was completed by Russian engineer troops well before their ouster in 1977. The quality of Russian construction of fitted armor stone protecting causeway and dikes at the end and back of the quaywall was quite good.



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Perhaps one phenomenon the Russians had not foreseen was the large runup heights that occurred due to the smoothness of the fitted stone. The wave runup undercut the base course underlying the asphalt pavement of the causeway resulting in extreme deterioration of the pavement. The apron on the existing quay was constructed as portland-cement concrete pavement with minimal reinforcement and was placed on a base course of stones approximately 5 to 8 in. in diameter. Cracks and cavities due to spalling were evident throughout the apron and concrete pile cap, reflecting the lack of quality control. Close observation indicated the possibility that a lean mix coupled with not observing the rules of hot weather concrete placement may have been the cause of the cracking and spalling.

## Quality Assurance

Under the formal provisions of the construction contract, the implementation of a contractor *inspection* system was specified. The requirement for this system, called contractor quality control (CQC), was predicated on the contractor's being ultimately responsible for quality and being best able to control quality. The contract articles addressing contractor quality control stipulated that the contractor organize and support the *inspection* system within his organization and that a functional manager, called the construction quality control representative (CQC REP) act as the head of a group of construction quality control inspectors with duties of controlling work activities to produce a quality product in compliance with the contract requirements. To accomplish construction control, the CQC organization was also required to utilize a three-phase construction control system of preparatory, initial, and follow-up inspections for each definable feature (element) of work.

The preparatory inspection entailed the taking of actions prior to the start of each definable feature of work (such as soil stabilization and compaction, pile installation, construction of concrete pile cap, etc.) to avoid mistakes that could result in a substandard quality product and necessitate rework. Such actions included obtaining shop drawing approval, formulation of mix designs, submittal of test reports such as specific gravity and absorption of aggregate, physical checking of construction materials including steel sheet piles and cement, performance of equipment safety checks, and inspection of work area.

The initial inspection entailed the establishment of standards of workmanship and ensuring that each definable feature of work was started correctly. In the initial phase, after a definable feature of work had commenced, the inspector was expected to verify that the materials furnished were the same materials that were approved, that the materials were not damaged in handling and storage, and that the workers understood the requirements for workmanship. Requirements for workmanship vary from project to project, and workers have a tendency to perform work as they did on their last project. Armor rock placement on a dike, using a crane fitted with an orange-peel bucket, must be carefully accomplished to maximize interlocking, for instance. This activity needs particular attention at the outset if the foreman has just come off a job where end-dumping was utilized to construct a revetment for which interlocking was not utilized in the design.

The follow-up inspection consisted of checking for continuation of compliance with contract requirements.





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The contractor inspection system was required to be complemented on this project by a government quality assurance system. The assignment of a resident engineer to Mogadishu, an engineer officer to Berbera, and the writer's appointment as supervisory civil engineer in June, 1983 signalled the beginning of the U.S. Government's buildup of its resident engineer office staff. The duties of the supervising office and technical staff at the construction office at Berbera, administering the construction contract under the resident engineer, and being the "quality assurance engineer" were delegated to the supervisory civil engineer by the resident engineer. One responsibility, as quality assurance engineer, was to assure that the contractor quality control program was functioning properly. This entailed planning and organizing the surveillance of construction to systematically monitor CQC operations and monitor the performance of preparatory, initial, and follow-up inspections. Surveillance involved quality assurance personnel's spot checking material and equipment delivered to the site, spot checking work in place, witnessing contractor's tests to verify test procedures, checking the calibration of the contractor's laboratory equipment, reporting, recognizing problems with CQC, and taking timely actions. A second responsibility was planning and organizing the inspection of construction for acceptance purposes. Prior to acceptance and payment, acceptance inspections to assure that the contractor's work was in compliance with the plans and specifications were performed as work (which would be concealed later by other work) was accomplished. Both surveillance and acceptance inspections were performed daily by quality assurance personnel but were performed in different manners and for their different purposes. Surveillance was performed by spot checking the contractor inspection system to insure that it was functioning properly, whereas acceptance inspections involved careful investigation of the work to determine compliance by the contractor with plans and specifications.

## Challenging Situations

In addition to the harsh environment, other problems occurred which taxed our ability to assure quality and manage the contract.

1. The contractor was unfamiliar with the three-phase control system required by the formal provisions of the specifications.
2. Lack of skilled workers in the Somali work force and cross-cultural differences had an impact. The indigenous workers on the port project were people of the desert who admired cleverness and living by one's wits. They thought of working with one's hands degrading. With tremendous cross-cultural differences between the Americans and Somalis, it is small wonder the American supervisors were at cross purposes with them half of the time.
3. The CQC REP was constrained by company management to hire indigenous CQC inspectors. Hiring a Somali employee cost approximately one-tenth of what it cost to hire an American. Unfortunately the Somali CQC inspectors had limited qualifications due to lack of experience and technical training to perform assigned responsibilities of observing, controlling, and reporting quality of materials and workmanship.
4. There were an insufficient number of qualified foremen and skilled workers on the job site to prosecute the work in such manner as to insure its com-

pletion within the time and quality requirements specified in the contract.

5. The civil superintendent in charge of the site and civil work was not diligent in performing the work according to the plans and specifications.

6. Conflicts occurring between one of the quality assurance personnel and the CQC staff resulted in resentment.

7. The turnover of project managers was atypical; the contractor had four different project managers during construction of the project which disrupted continuity. Each new manager had not personally experienced what had transpired previously on the job site and had to learn to adapt and cope with construction in Somalia.

8. Berbera was the main port in Somalia from which livestock was shipped. In late July, 1983, the town and port of Berbera was suddenly overrun with goats, sheep, and camels enroute from the interior of Somalia to the abattoirs of Saudi Arabia. Unloading by the contractor of LASH barges containing construction material and equipment had to compete with the loading of livestock bound for Saudi Arabia. The use of tact in dealing with public officials who ran the port was imperative. Fortunately the port director was quite reasonable and gave our discharge of construction material high priority even when livestock were waiting to be loaded onto dhows and ships.

9. There was restriction of freedom of movement because of the region's having been placed under martial law due to terrorist incursions. The Somali Army, who had the responsibility to keep order, was nervous with good reason since the Berbera hospital was full of their wounded comrades. Most of the incidents occurred many miles away. However, it was very unsettling to be held at gunpoint on a regular basis until one was able to prove who he was to the Somali officer or NCO in charge. After several weeks the soldiers became used to the Americans and their white trucks, and the pointing of weapons became much rarer. The efforts of the Somali Army in protecting U.S. Goverment and contractor personnel from possible mischief from terrorists were appreciated. Armed military guards protected the labor camp from late August, 1983, until construction of project was completed in early 1985.

10. Minor theft of construction materials by host country nationals and infrequent interference by the Somali Army with construction operations caused problems for a short time, but the Somali goverment interceded on the contractor's behalf to almost completely stop the theft and interference.

11. It was suspected about halfway through the project that the contractor had underbid the job due to his not realizing the expense of producing in Somalia.

## Prosecution of Work

In December, 1983, and January, 1984, the resident engineer office staff was supplemented with two quality assurance personnel who were added to perform quality assurance surveillance and inspections. The actual work had begun in October, 1983, just after mobilization had ended. The supervisory civil engineer, in his role of "quality assurance engineer," began planning, organizing, and administering the field surveillance of the CQC organization's performance which entailed scheduling of joint contractor–government preparatory, initial, and follow-up inspections to monitor how well the CQC was controlling construction quality during each of the three inspections. In addition, he assigned, directed, and reviewed the work of quality assurance personnel with an eye to increasing the efficiency of their perfor-





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mance and getting top-notch daily acceptance inspections. These daily inspections were of work which would later be concealed by other work. The quality assurance personnel's duties were to observe and report quality of materials and quality of workmanship, recognize problems with the CQC, and take timely corrective actions.

After completion of mobilization and construction of the labor camp in August, 1983, the contractor commenced to augment his work force to prosecute to completion the work he was being paid to do. Site work including demolition, excavation, and disposal was started, and construction of the causeway core commenced. Huge stones several tons in weight, removed during demolition of the existing Russian-built dikes, were broken into usable armor stone sizes so they later could be incorproated into the work. Jackhammer holes were drilled on 1-ft centers and light charges were used to split the rock on the drill line; this armor stone and additional armor stone manufactured at the quarry was later lifted and lowered into position onto newly constructed dikes by a crane fitted with an orange-peel bucket. One first sensed the contract's beginning to go awry during construction of the causeway. Construction of the causeway was not clearly covered in plans and specifications, so an agreement was made between the projet manager and the resident engineer in July, 1983, to specify composition of the core. It was agreed that the core was to be constructed from quarry waste with rock no larger than 10 in. in diameter. In August the civil superintendent began placement of stones into the core with diameters as large as 60 in. He was reminded of the agreement between the project manager and the resident engineer that no rock greater than 10 in. in diameter would be used so as to not adversely affect subsequent densification of the core. The reminder was to no avail. The incorporation of huge boulders continued. Stern action was finally required to force the civil superintendent's adherence to the agreement.

In December, 1983, and January, 1984, when site work was largely completed and earthwork and concrete placement had been started, the daily reports filled out by quality assurance personnel described in detail what was observed during field surveillance of CQC operations and daily acceptance inspections. These reports provided written evidence of the contract's having gone awry. Fill, grading, and compaction were being accomplished without use of grade and slope stakes, and lifts were too thick. During concrete placement, rules for good concrete placement were broken. By the beginning of February, 1984, the evidence was mounting that preparatory, initial, and follow-up inspections repeatedly were being poorly performed by CQC inspectors. Time was spent considering carefully the various instances of poor quality, and it was decided that the three worst causes in order of severity were poorly performing CQC inspectors, insufficient number of qualified foremen and skilled workers, and the civil superintendent's not performing work in accordance with the plans and specifications. Letters were sent to the contractor to get him to improve his performance; the letters also documented poor quality. However, the quality of construction did not improve. The CQC inspectors continually accepted flagrantly bad work. The CQC REP was the only person in the CQC organization with the knowledge, abilities, and skills required for construction inspection and control work. Unfortunately he could not be in several places at one time. Due to the rate of "construction put in place" on the $35,000,000 project, one qualified person





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on the CQC staff was totally inadequate to maintain quality. Additional letters were written addressing the consistent poor performance of CQC inspectors and poor quality. By the end of February quality still had not improved.

A slightly different tack was taken. In consonance with the general provisions, weekly meetings were held beginning in late February with the CQC REP, supervisory civil engineer, and engineer officer in attendance. By request, the project manager also attended the first meeting. At the first meeting and at each subsequent meeting, concerns about poor quality and the poorly performing CQC inspectors were voiced. It was emphasized that the U.S. Government was not satisfied with the quality being produced and was not satisfied with the use of indigenous inspectors who were unqualified and unable to exert control. Concerns about poor quality and inspectors were also communicated several times to the project manager both orally and in writing. Care was taken to only suggest and not to instruct the project manager in order to avoid any possible basis for a future claim.

Neither the project manager nor the CQC representative appeared to acknowledge the fault. This syndrome had been detected on other jobs in the past where poor quality subsequently disappeared after such a meeting though no one acknowledged the fault. It was hoped that such would be the case here since the resident engineer office staff was disinterested in what was acknowledged as long as the problem of poor quality was rectified. However the problem of poor quality of construction remained unresolved.

Portland-cement concrete placement was the most evident example of a definable feature of work for which quality was not being controlled. The CQC inspectors did not know that dowels at contraction joints in pavement needed to be greased, that water could not indiscriminately be added to concrete to increase workability since the water-cement ratio might be unacceptably increased, that the temperature of concrete at placement could not be greater than 90° F, and that burlap covering concrete surfaces must be kept continuously wet to maintain a moist environment. In addition, the faulty workmanship, due to the civil superintendent's being unfamiliar with the specifications and with good construction practice, exacerbated the problem. The temperature of concrete at placement was often considerably in excess of 90° F, burlap covering concrete surfaces was dry for hours at a time, dowels at contraction joints went ungreased, and water was indiscriminately added to concrete under the watchful gaze of the civil superintendent and the CQC inspectors. Concrete with a temperature greater than 90° F, due largely to hot aggregate and hot mixing water, was placed into forms; patterns of large cracks emerged during hydration. The pavement slabs, consisting of this concrete, invariably had to be removed with jackhammers and replaced. Apparently the cracking of the concrete was due to a combination of rapid evaporation of water and increased drying shrinkage due to the concrete's high temperature during placement.

Quality control and quality assurance did not supplement each other. Quality control often did not avoid construction deficiencies and did not detect them. The supervisory civil engineer also became aware that the contractor had begun to rely on resident office staff to do the job that quality control inspectors should have been doing. Flagrantly bad work was frequently not being rejected by the CQC, and quality assurance personnel and the supervisory civil engineer began rejecting such work. However, since our purpose





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was to *assure* that the U.S. Government was obtaining the quality purchased, and not to perform the quality control function, the resident engineer office staff was doing the job that the U.S. Government was paying the contractor to do. Quality assurance and quality control were not proceeding simultaneously for their different purposes. The double check that quality assurance should have provided was nonexistent. Getting the contractor to correct grossly bad workmanship found by the resident engineer office staff was not difficult to accomplish due to the clarity of the plans and technical specifications and the enforcement power given the U.S. Government by clauses in general provisions addressing "material and workmanship" and "inspection and acceptance." However, the most frustrating aspect was the borderline cases. Leaving slabs in place that were marginal and letting fill remain that had barely passed compaction tests gave little satisfaction because one knew the entire job was not a good job even though some of the work was not bad enough to warrant rejection. The job needed to be turned around, and the CQC had to be made to work. This proved to be very difficult to accomplish.

The aggressive action that would ordinarily have been taken after having sensed a contract going awry was not taken because of a fear of an adversarial relationship with the contractor which could have had disastrous consequences. The four personnel at the job site who represented the U.S. Government (the supervisory civil engineer, engineer officer, and two quality assurance personnel) were living in the contractor's labor camp and eating at his mess hall on an isolated job site in a desert 1,000 miles from the nearest large city. The resident engineer had made it clear at the outset of the necessity of avoiding an adversarial relationship. In relation to the poor construction quality, responses to the contractor that would normally have been made were modified to avoid an adversarial relationship. The hardships in this remote, dry, hot, unpleasant environment were difficult enough to cope with. An adversarial relationship would have proven to be a major problem.

Beginning in March, 1984, the pressure was escalated. Correspondence to the contractor was continuously generated in order to further emphasize, to the contractor, that action needed to be taken and to further document the poor construction quality. By this time poor quality pile construction had surfaced. Pile driving operations were not being adequately controlled. The row of piles forming part of the face of the anchored bulkhead was driven out of alignment. The piles were pulled, driven again, and were still out of alignment. More letters were sent to the contractor addressing poor quality, poorly performing CQC inspectors, lack of qualified foremen and skilled workers, and performance of the civil superintendent that was not up to expectations. These letters pointed to earthwork, concrete placement, pile construction, and other definable features of work that were of poor quality due to poor inspection, lack of qualified workers, carelessness, bad judgement, and lack of control. It was repeatedly pointed out that construction deficiencies were being neither prevented nor detected and that rework, necessitated by poor workmanship, had become the rule rather than the exception. After having written many letters, still no action was taken to improve quality. Finally, in May, 1984, construction began to get behind schedule. The quality assurance engineer's initial approach to assure quality had not succeeded. However, written documentation of the lack of control of field operations and poor quality was substantial, and over 100 photographs of poor quality had been taken by quality assurance personnel. The resident engineer, who resided in the capital city of Mogadishu some 1,000 miles away, came to Berbera on an extended trip in May, and it was concluded that the construction quality problem had gotten entirely out of hand. It was also decided that aggressive action would be taken to cause the contractor to produce the quality that the government was paying for.

A calculated risk was taken. Though there was the possibility of fomenting an adversarial relationship, a large sum of money was retained from the monthly payment estimate in accordance with the general provision addressing payments to the contractor; poor construction quality was cited as the reason for retention. However, no action was taken by the contractor, and the quality did not improve. The following month, another large sum of money was retained from the monthly payment estimate.. An exceedingly large total sum of money had now been retained, and the consequent reduction of cash flow got the attention of the owner-president of the construction company; he made a special trip to Berbera for a conference. It was clearly and firmly explained at this conference that continuation of poor quality could and would not be tolerated.

As a direct result of the conference, two highly qualified quality control inspectors, a site superintendent, three foremen, concrete finishers, and other skilled construction workers were added to the work force. In addition, the contract of the poorly performing civil superintendent had run out and was not renewed, and the indigenous CQC inspectors were laid off. The turnaround was phenomenal.

The job began to run itself. Contractor quality control and Government quality assurance began working together cooperatively to control and verify the quality of work required by the contract. A system was implemetned where aggregate was sprayed to reduce the temperature of the concrete during placement. The temperature of the concrete at placement was reduced to well below 90° F, and the cracking ceased. Concrete placement, soil stabilization and compaction, and pile driving were done right the first time; rework was practically eliminated. By December, 1984, the contractor was well ahead of schedule and nearing contract completion.

## Quality Assurance Lessons Learned

It is easy to those closely involved with a project to be wise after the event and to pontificate afterwards on the need to apply specific insights and principles of quality assurance promptly. It is much more difficult to have to make quality assurance desicions on site when the problems are actually occurring. It is hoped that the following lessons that were learned will ease the difficulty of making quality assurance decisions in the field and prove useful to those assuring quality of construction in Africa.

### Lesson 1

Quality control inspectors must be fully qualified by experience and technical training to perform the control requirements.

### Lesson 2

If a job gets going on the wrong track early in the contract, due to poor performance of quality control organization, and no action is taken, it is very

very difficult to turn the job around. If one senses a contract going awry early, not only take aggressive action at once but also be careful to keep accurate (written and photographic) records to document all instances of the contractor's lack of planning, scheduling, and control of field operations. Extra care should be taken to describe in detail wasted time. This will provide an invaluable record in the form of vital irrefutable evidence that the contractor is to blame for delays and faults in his own work, in the event that adverse action should subsequently become necessary.

**Lesson 3**

Do not let the quality assurance personnel do the job of the quality control inspectors. When the quality assurance personnel detect specific construction deficiencies, do not inform quality control personnel of them. State simply that another preparatory, initial, or follow-up inspection is needed. If a quality control inspector asks why, tell him that if he reads the specifications he will know why. This should get quality control personnel to correct the construction deficiencies that were detected and get them to prevent others. Should the quality control personnel begin relying on quality assurance personnel to detect deficiences, control will quickly disappear. The double check needed for obtaining compliance will be circumvented.

**Lesson 4**

Pay particular attention to monitoring preparatory and initial inspections to assure that workmanship standards are established at the outset of a definable feature (element) of work. To look over the shoulder of quality control inspectors, schedule the quality assurance personnel to be at a maximum number of preparatory and initial inspections early in the contract.

**Lesson 5**

Intermittently ask the quality control personnel pertinent questions about the specifications. This encourages them to dig into the specifications. They cannot do a quality job without being intimately familiar with the specifications.

**Lesson 6**

Be certain that the quality control personnel develop and utilize checklists for initial and preparatory inspections.

**Lesson 7**

Assign one individual as coordinator with the manager of the quality control organization on quality control matters to keep him from shopping around.

**Lesson 8**

The whole quality control system is predicated on prevention. Schedule a meeting before the contract starts to address quality control. Show the contractor at the meeting that prevention is to his benefit financially. If rework is necessitated, the contractor will reduce his profit margin. (If a contractor loses money due to rework, he may submit claims to the owner for all extras. When a project is being constructed within cost, such claims may go unfiled.)

**Lesson 9**

Ascertain that the staff of the quality control organization is adequately sized to maintain quality. For example, in pile construction have a minimum of one quality control inspector per pile driving rig and one supervisor per eight inspectors.

**Lesson 10**

Have a "Material and Workmanship" clause in the general provisions to allow the Engineer to remove from the work any employee of the contractor whom the Engineer deems incompetent. Use the clause to remove incompetent personnel.

**Lesson 11**

To better establish a system of assurance that the owner will receive that which has been contracted, it is recommended that the quality assurance engineer develop a written quality assurance plan addressing planned systematic surveillance to daily document the performance of quality control inspectors and addressing daily inspection for purposes of acceptance and payment.

1. As part of the plan, develop a report to be filled out daily by quality assurance personnel. Have sufficient space for the quality assurance personnel to comment on the results of spot checking work in place, progress, and equipment and material delivered to the site. Also provide space for noting deficiencies, reporting on observation of testing procedures, and describing instructions given by quality assurance personnel to CQC inspectors or contractor personnel.
2. Determine each definable feature of work that the project entails (such as cast in place concrete pile cap, fill and compaction behind bulkhead, pile construction, and installation of anchorage) and formulate guidelines to determine what is to be surveilled by quality assurance personnel for each definable feature of work. Prepare a separate surveillance checklist, incorporating the guidelines, for each definable feature of work. The checklists are to be filled out by quality assurance personnel in conjunction with the aforementioned daily report to document satisfactory or unsatisfactory performance of quality control inspectors at preparatory, initial, and follow-up inspections.
3. Plan surveillance by scheduling quality assurance personnel to be at a maximum number of preparatory, initial, and follow-up inspections to spot check equipment and material delivered to the site, work in place, and testing.
4. Schedule performance of acceptance inspections by quality assurance personnel of work which will be concealed later by other work. Have quality assurance personnel indicate on the daily report work not complying with contract requirements.
5. Formulate performance standards that the quality assurance engineer can use to determine satisfactory or unsatisfactory performance of the quality control representative and inspectors. (Falling below such standards may necessitate notifying the quality control representative and project manager in writing of poor quality and unsatisfactory performance.)
6. Develop a format for the quality assurance engineer's monthly evaluation of quality control's performance. An uncomplicated format with a written evaluation documented by surveillance reports and checklists filled out by quality assurance personnel has proven to be sufficient. Recommendations for nonpay-

ment for items of work not complying with plans and specifications and recommendations for deductions should be incorporated into the evaluation.

**Lesson 12**

The reluctance of a contractor to allocate sufficient resources (money, skilled workers, and foremen) to a project results in poor workmanship, poor quality, and delays.

**Lesson 13**

In the case of a potential dispute, keep accurate written and photographic records. Such records serve as evidence for those making judgments on the validity of contentious claims for extensions of contract time or additional compensation. When disputes are finally settled, the resident engineer office staff may have begun to move off to other contracts, memories may have faded, and the task of sorting out what actually happened becomes more difficult without such site records.

**Lesson 14**

Be careful that quality assurance personnel do not tell the contractor something that changes plans and specifications. This could result in a change order.

## Quality Assurance Conclusions

Construction work in the unusually harsh physical environment of Somalia proved to be a reasonable facsimile of work prosecuted in climes offering more favorable enviromental conditions. It can be generalized that, if a contractor inspection system (contractor quality control) is required by general provision of a contract, the only way the contractor inspection system is going to work is if the quality assurance engineer forces the contractor to make it work. *The easiest way to make it work is for the quality assurance engineer to show the contractor he means business early in the contract.* In the case reported herein, extraordinary efforts were needed to make the CQC work on a project where mixed work crews composed of Somalis, Fillipinos, and Americans placed the work. It is a tribute to those who created the contractor quality control system concept that it did work as well as it did in this working environment.

## Proven-in-Action Success Techniques

The harsh physical environment of the Horn of Africa requires unique consideration in construction. The contractor in Africa has much to gain from expeditious, economical field operations. Production costs vary almost directly with time, and expeditious job completion can mean appreciable overhead savings. Failure to comply with contractual time requirements is a breach of contract, making the offending contractor liable for damages to the owner (liquidated damages). Even if overhead savings or damages were not at issue, the contractor's own self-interest dictates that he complete his project on time. A reputation for timely project completion is an intangible asset of considerable value to a contractor.

The following proven-in-action success techniques were developed by project managers, foremen, and craftsmen to cope with the unusually harsh physical environment of Somalia and to get the job done in the context of the Somali culture. Constructors in Africa may find the following list of suggestions useful.

1. A floating driver, assembled by placing a land driver on a barge with winch engines for the fore, aft, port, and starboard lines, works well when there is a large number of piles to drive. The floating rig proved to do a superior and quicker job. Driving piles through water from land is inefficient.

2. The use of a template (with one set of guides, two horizontal guide wales, and spacer blocks) to secure proper alignment of steel sheet piles through water is recommended. The template aids in securing proper horizontal, vertical, and longitudinal alignment of piles. Pile driving without the template proved to be inefficient since there was only 1/4 in. of play available when lining up the interlocks; production was dramatically increased when the template was used.

3. Rainstorms along the Indian Ocean coastline occur with very little advance warning. Quantities of uncovered cement lying directly on the ground were lost during a storm. Protecting hydraulic cement from the elements to prevent unintended hydration is suggested.

4. Use of a crawler-mounted bulldozer in lieu of a wheel-mounted bulldozer in quarries is recommended due to the sharpness of rocks encountered in the region.

5. Coral outcrops above and below the ground abound adjacent to the coast. A tractor-mounted hydraulically operated ripper is extremely effective for ripping dead coral rock and hardpan. The use of jackhammers was very ineffective for removing coral.

6. A slurrly (made by blending inert gel, ammonium nitrate, and aluminum particles with water to produce the desired consistency) proved to be well suited for blasting. The slurry was poured directly into the holes, prima cord was used for detonation, and the tops of the holes were filled with stemming consisting of rock cuttings. The degree of fragmentation produced by the explosive was more than adequate.

7. The performance of the construction equipment with internal-combustion engines including dump trucks, front-end loaders, bulldozers, backhoes, and motor graders became sluggish during the hot season due to the lower horsepower they developed. A contractor who has established production rates for his equipment in more moderate climates will make a serious mistake if he uses those production rates in bidding a job to be constructed on the Indian Ocean coastline. A correction factor must be applied.

8. The high solar radiation and heat are oppressive during the hot season. Getting rid of heat produced by the body is a problem. Work should be performed in the shade whenever possible to prevent heat cramps and heat exhaustion. At the minimum a shaded shelter should be provided at the work site to provide a respite from the sum. One should cover his head to prevent its exposure to the sun. Plan on effeciency and production rates being reduced in the hot season (from June through September), highly consider using night shifts, and do not forget to include the cost of lighting (for work in the dark) in your estimate.

9. During the monsoon season, increased maintenance of vehicles is necessary due to blowing dust and sand. A high priority should be given to the





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provision of replacement and repair parts. Vehicles should be lubricated and oil changed every two weeks.

10. Tires on all vehicles deteriorated rapidly due to the heat. Provide many extra tires due to the frequency of tire replacement.

11. Vehicle batteries tended not to operate at full efficiency at high temperatures. Consider using larger than standard sized batteries.

12. During the rainy season, flash floods can occur unsuspectingly in response to rainfall input. Large flood flows occur because of the rainfall intensity and the impermeability of parts of the watersheds. It is of great importance to locate labor camp, warehouses, material storage areas, repair shops, the reinforcement steel fabrication shop, carpentry shop, and batch plant out of the flood plains of stream beds. In addition, do not store materials or construct temporary buildings in low points and depressions where there will be a collection of runoff and subsequent ponding.

13. The overheating of engines in trucks and other construction equipment is a recurring problem. Spare parts for cooling systems are recommended.

14. Road construction equipment may need to be modified due to dust and the abrasive action of sand.

15. The most difficult area of quality control is concreting in hot weather. Cost overruns for the replacement of concrete that had not cured properly due to heat were large. Cooling the aggregate by spraying with water and proper curing were the keys to preventing cracking and getting the required 28 day compression strength of 3,000 psi.

16. Some aggregate sources were found to be contaminated with chlorides and sulfates and were unsuitable for use in concrete.

17. Limestone and dolomites were found in hilly areas; they make good coarse aggregate and armor rock soures.

18. Corrosion is a problem. A rust bloom on a steel sheet pile sandblasted to white metal will form within a matter of hours. Coatings need to be applied immediately after sandblasting.

19. Potable water stored in dark steel tanks can reach extremely high temperatures when exposed to the sun. Such high temperatures can lower the chlorine residual of treated water below acceptable levels, resulting in illness.

20. Sand of sufficient quality for sandblasting is scarce. When sandblasting to white metal, the indigenous sand did not work. Sand had to be imported for this purpose. Garnet proved to be particualrly effective.

21. Trailers and portable buildings may be toppled during the monsoon season. The use of deadmen anchors to tie down buildings is recommended. Piers supporting portable buildings should be as short as possible.

22. High temperatures may adversely affect the performance of generators. Engine-generator sets should be shaded from direct sunlight to prevent overtemperature shutdown. Engine-generator sets should be protected from blowing sand and dust and should be sited on a line perpendicular to the direction of the prevailing wind so that convection will not transport heat from one generator towards another. An accelerated maintenance schedule for the generators is highly recommended.

23. Due to rock or organic coral below the ground surface, it may be necessary to drill the holes for generator ground rods to the necessary depth and surround the rods with bentonite or other suitable material. The use of copper grounding rods is recommended as corrosive soils in the region may cause rapid deterioration of galvanized steel grounding rods.

24. The use of an underground electrical distribution system at the job site is recommended to protect against deformation and deterioration of insulation from direct sunlight and the blowing down of power lines by wind.

25. Due to blowing sand and dust, a protected maintanance area is required for construction equipment and vehicle repairs.

26. Fuel was lost due to thermal expansion when fuel tanks of vehicles were completely filled.

27. Protect fuel reaching high temperatures by burying gasoline and diesel storage tanks. In addition to safety considerations, gasoline may degrade at high temperatures.

28. Trailers and portable buildings may be set with their longitudinal axes in an east-west direction to minimize wall exposure to morning and afternoon sun. Inside temperatures and air-conditioning costs will be minimized.

29. Wind during the monsoon season is a major climatic force which must be planned for; the wind moves great amounts of hot air and dehydrates the workmen. Large quantities of water must be provided.

30. Pile driving through water cannot be accomplished during the monsoon season even with a jackup barge due to the magnitude of wave heights.

31. Anopheles mosquitos can be a problem. Taking Aralen regularly and applying larvacides to adjacent marshy areas to kill mosquito larvae are worthwhile precautions.

32. Complete all piling work, including welding, tie rod connections, tie rod tightening, and waler installation before the pile cap is placed.

33. Do not drive piles within 100 ft of concrete less than seven days old. The vibrations damage green concrete.

34. Do not use cloth tapes, due to their tendency to stretch. Consider providing work crews exclusively with steel tapes.

35. Be cautious when jetting. Jetting can produce undesirable side efects including damage to adjacent existing marine structures, cutting a pathway through semipervious strata and letting the hydrostatic pressure act on the entire length of the pile, and loosening and causing the leaning of adjacent previously driven piles.

36. Consider carefully the type and weight of the hammer or type and size of vibratory driver to be used. (Improper matching of the hammer to the pile causes pile head damage.)

37. Consider using a vibratory hammer if a large number of piles are to be driven since vibratory drivers are more efficient and cause considerably less damage to a pile during driving than impact drivers. (Less damage occurs because vibratory drivers operate with a controlled steady-state vibration and do not cause impact at the head of the pile. In addition, the forces at the tip of the pile are considerably less than that for impact driving and a much lower potential for damage exists.)

38. Be careful about instructing indigenous workers not to dump concrete into pipe piles through water. Closely supervise them when cleaning debris and soil out of pipe piles and draw the water down to a depth of 2–6 in. before concreting.

39. Drive sheet piles with the tongue of the section leading in the direction of driving.

40. Place and compact backfill around anchorage before filling against the bulkhead.

41. Backfill should be placed by working away from the bulkhead rather than

toward it. This will reduce lateral loading and minimize the probability of failure during construction due to the bulkhead's being unable to withstand the lateral pressure of the earth.

42. When making field splices of steel sheet piles, it is obviously important to line up the interlocks perfectly. A good jobsite method which unskilled workers seem to readily understand is to take each side of the two pieces which are to be spliced and thread them into the interlock of a single section. This single section should extend 5 ft or more on each side of the joint.

43. Field splices of H-piles are are most reliable when full penetration butt welds are used. Consider accomplishing splices of H-piles using sleeves and 5/16 in. (or heavier) fillet welds along the full width of each flange and at each corner.

Although much of this information may seem fundamental and obvious, it was purposefully included because the information represents statements of principles and illustrations that ought not to be ignored.

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