HEAVY-DUTY PAVEMENT PROCUREMENT MIT PANAMA EXPERIENCE

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ABSTRACT

Manzanillo International Terminals (MIT), located on the Caribbean side of Panama, is a fast-growing container terminal in the Americas. The terminal, which opened for business in April 1994, is now handling more than one million 20-foot equivalent units (TEUs) per year. The terminal's first phase consisting of 24 hectares of Portland cement concrete paving was completed in late 1995. Within four years of its construction, large areas of the container yard underwent settlement of up to 30 cm, which resulted in severe cracking and spalling damage to the pavement. Portions of the pavement were so badly deteriorated that they had to be replaced to prevent accidents. Based on business growth demands, in 1998 MIT began planning a 16-hectare expansion of the terminal. The expansion added new berths and container yard to a dredge spoil area to the south. Ground preparation for the expansion consisted of an extensive wick drain and surcharge program, which was devised to accelerate the settlement process. To improve performance and reduce maintenance, concrete block paving (CBP) was chosen for the heavy-duty container yard and was designed for rubber-tire gantry (RTG) and container top pick loading. This paper describes a coordinated approach designed for the ground preparation and pavement construction of the Phase II, 8-hectare container yard, as well as lessons learned in the construction of Panama's first heavy-duty CBP project.

1. INTRODUCTION

MIT is a privately financed, built, and operated container terminal in the city of Colón in the Republic of Panama. The terminal, which takes its name from the bay, is owned and operated by Seattle, Washington-based Stevedoring Services of America and their Panamanian partners. Construction of the Phase I terminal was completed in 1995. Figure 1 shows the yard improvements in 1995. The 24-hectare Phase I pavement was procured in two distinct methods. The first part, identified as Phase I-A (about 14 hectares) was procured on a design/build basis. The designer and constructor had no previous experience in heavy-duty paving. The site was poorly prepared with uncontrolled filling and inadequate compaction. The designer employed 30-cm reinforced concrete paving for most of the areas and 25-cm unreinforced concrete paving for areas that had older sections of concrete paving underneath. Within four years of its construction, parts of the area underwent settlement of up to 30 cm and displayed severe cracking and spalling. Some of these areas showed crazing and cracking of the concrete even before any terminal operations began. Poor performance of the pavement was a result of inadequate subgrade preparation and a poor concrete mix, compounded by the incessant rainfall (over 800 cm per year) and high-cycle loading by top picks. Portions of the pavement were so badly deteriorated that they had to be replaced to prevent accidents.

The second part of Phase I identified as Phase I-B (about 10 hectares) was procured on a design/bid/build basis. BERGER/ABAM Engineers Inc. designed this part with assistance from paving specialists.

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Construction documents (drawings and specifications) were prepared and bid to Panamanian and U.S. contractors. The contract was awarded to an experienced Panamanian contractor who had successfully completed several road and pavement projects in Central America. The paving design, consisting of a 30-cm plain concrete section over a 25-cm gravel base, was placed over a well-compacted subgrade. Construction of the Phase I-B project was supervised by experienced personnel and is performing very well today.

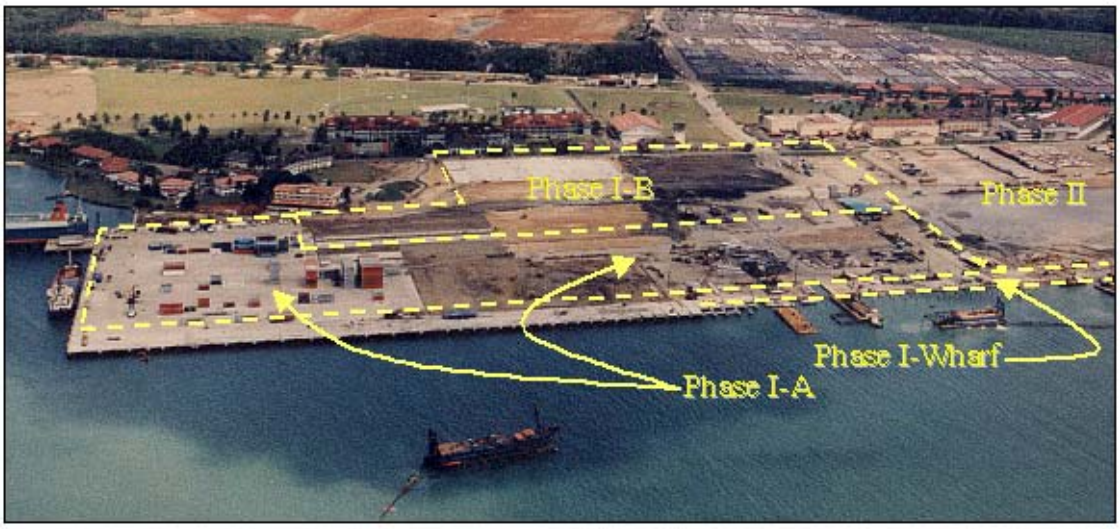


Figure 1. MIT existing (1995) and future yard improvements.

Drawing on the successes of the Phase I-B pavement procurement, the owner retained BERGER/ABAM to design improvements of its 16-hectare yard expansion project. The early objective of the design team was to implement a plan that went beyond engineering design to include all project phases from concept to construction. BERGER/ABAM terminal experts designed a holistic approach to pavement procurement that made emphasis on four key elements: appropriate pavement selection, detailed design and specifications documents, experienced contractor, and a rigorous quality assurance and inspection program.

2. PHASE II - RECLAMATION AND GROUND PREPARATION

The area for the Phase II expansion was the previously created dredge spoil area from the Phase I channel and berth dredging. The dredged fill materials were a mixture of bay mud, coral, and broken-up siltstone called "gatun." The filling operation was mostly uncontrolled with no attempt to engineer the work. This was deliberate because the owners were more interested in reducing Phase I costs and survive as a business. However, once they decided to proceed with development of Phase II terminal areas, they were willing to properly engineer the project and construct a trouble-free pavement.

The ground improvement program for the new project was designed to support container stacking six boxes high and operation of top picks and RTG cranes. The 16-hectare Phase II area was confined by a sand/coral dike to the west, existing terminal to the east and north, and a drainage canal to the south. A United States-based geotechnical consultant was retained to perform a thorough investigation of the site. Fourteen soil borings were taken throughout the site for depths exceeding 20 meters from the existing ground elevation. To no one's surprise, the geotechnical consultant quickly established that up to 15 meters of highly compressible materials existed at the site and that a ground improvement program was needed to consolidate the soils. After studying all the pertinent soil properties, a wick drain and surcharge program was devised to accelerate the settlement process.

The wicks were to be placed at 3-meter centers in a triangular pattern for a 3-meter-high surcharge and for a two-year time frame. Increased wick spacing was needed near the new wharf edge, where the full surcharge height and time frame were not feasible due to ongoing operations. Wick drain length varied between 10 and 20 meters. It was also decided that the area would be improved and paved in two 8-hectare segments to optimize costs.

3. PAVEMENT UTILIZATION

Prior to selecting the pavement type, the design team obtained a clear understanding of the desired pavement utilization from the owner. MIT owners desired to construct a pavement system that would support varied operations for different types of container-handling equipment ranging from top picks to RTGs. Designers used this information to craft an effective usage plan for the new yard. Figure 2 shows the resulting pavement utilization plan for the yard.

The 8-hectare container yard is rectangular, 350 meters long and 225 meters wide. Approximately one-third of the yard was designed for top pick operations, having a 120-ton front axle load. The remaining yard was designed for container stacking by RTGs running along dedicated paths.

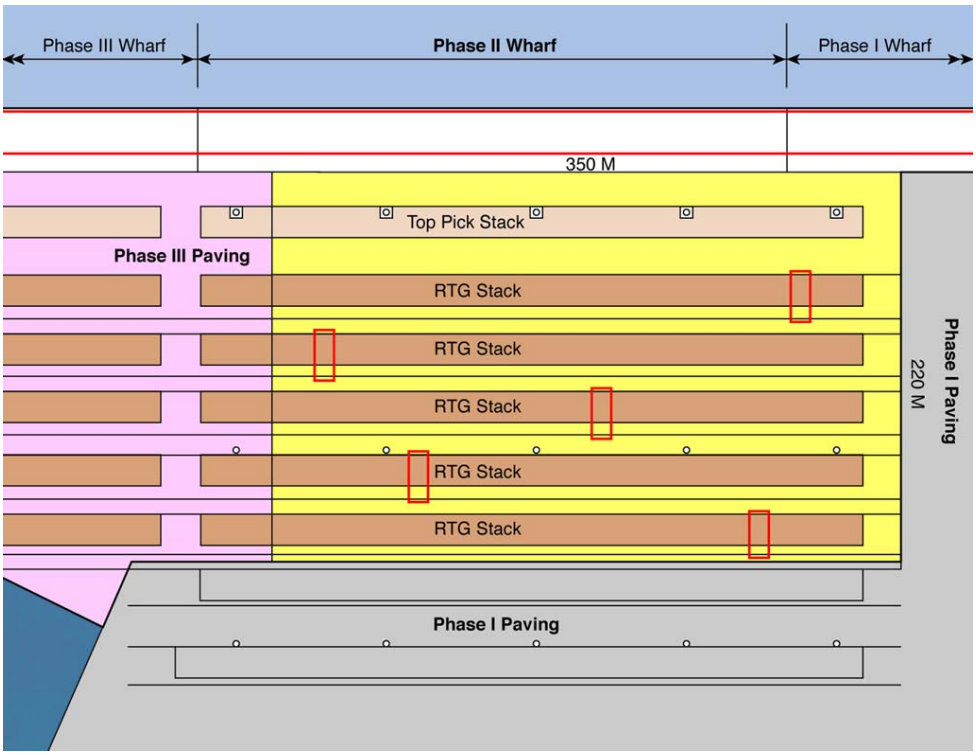


Figure 2. MIT pavement utilization plan.

4. PAVEMENT SELECTION AND DESIGN

Varied operations at the new facility presented an opportunity for segmental pavement design. This practice of segmental pavement design may reduce flexibility of container port use; however, it offers the advantages of reduced paving cost. Reduction of paving costs is achieved because segmental designs are not restricted to worst-case paving scenarios for the entire yard; rather, they employ appropriate cross sections depending on intended use.

In light of the Phase I pavement deficiencies, for the Phase II yard, the owner desired a pavement system that could be easily repaired and would perform well despite potential subgrade settlement conditions.

Several pavement alternatives, including concrete slab and bituminous asphalt, were considered for the project. Pavement alternatives were restricted by heavy rainfalls experienced in Panama, which could severely impact construction activities.

The selected pavement system consisted of heavy-duty CBP over bedding sand, cement-treated base (CTB), crushed rock base, and compacted sand subbases. Rectangular pavers measuring 105 by 210 by 80 mm placed at a 90-degree herringbone pattern were specified for the project. Yellow-colored pavers were specified for RTG tracks and stop bars throughout the yard. The CBP system was selected based on life-cycle costs, potential to handle future settlements, and ease of repair in discrete areas. .

As shown in Figure 3, the crushed rock base and CTB thickness varied across the yard to support the differing operations and loading conditions. Pavement thicknesses were determined by wheel load analysis performed in accordance with the British Ports Federation manual entitled "The Structural Design of Heavy Duty Pavements for Ports and Other Industries." In addition to wheel geometry and center of gravity position considerations for each equipment type, the analysis applied dynamic factors to represent lifting, breaking, turning, and other operational movements.

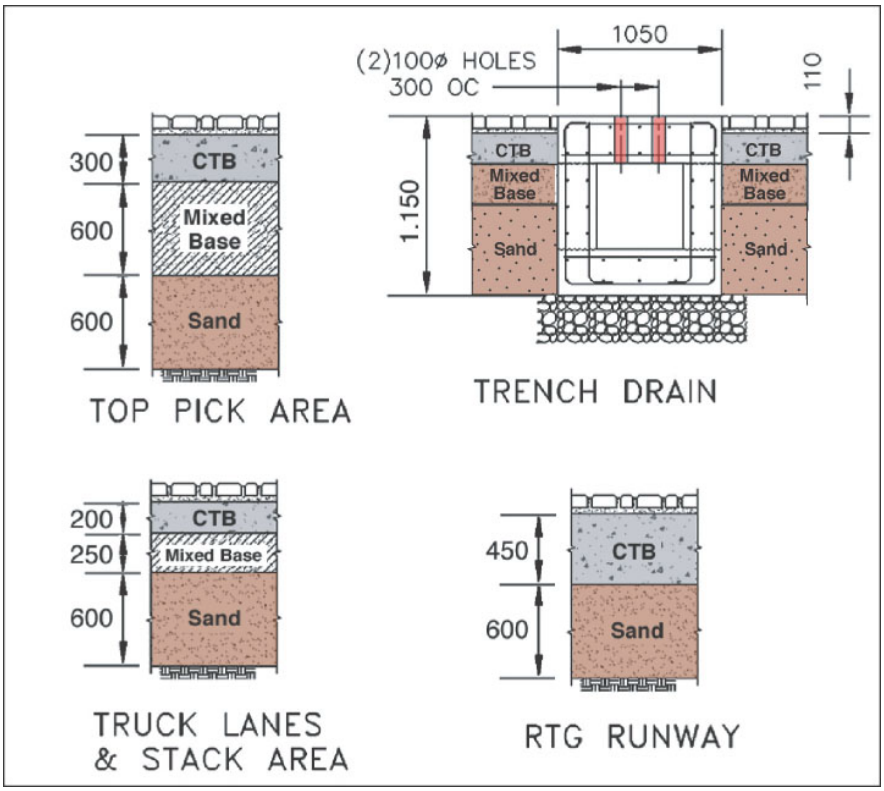


Figure 3. Pavement cross sections.

5. SPECIFICATIONS AND CONTRACT DOCUMENTS

A key component in the success of the MIT pavement project was the careful consideration given to the preparation of specifications and other contracting documents. Extensive planning and predesign testing minimized uncertainty and afforded a high level of detail in the specifications. Some of the special considerations applied in the specifications are listed below.

5.1 Sand Subbase

The contract specifications required the owner-supplied dredge sand to be placed in lifts not exceeding 30 cm and compacted to 95 percent of optimal density.

5.2 Mixed (Crushed Rock) Subbase
The contractor was to mix 25 percent of owner-supplied dredge sand with the well-graded crushed river-run rock and place it in lifts not exceeding 20 cm thick. Compaction was to be 98 percent of optimal density.

5.3 Cement-Treated Base
The composition of CTB consisted of adding water and 6 to 8 percent of cement to the mixed base in a pug mill. The contractor was to establish the cement content through trial mixes to obtain 800 psi compressive strength. Maximum placement thickness of 15 cm and compaction testing to 98 percent of optimal density were also specified.

5.4 Bedding and Joint Sand
Two different requirements were specified for the bedding and joint sands. In addition to specific gradations, the bedding sand specifications required compliance with a Lilley-Dowson degradation test. This testing procedure was required to ensure that bedding sand would withstand wearing from heavy wheel loads and high repetitions. A 25- to 30-mm thickness was specified for the bedding sand layer. Joint sand stabilization was accomplished through applying a water-borne sealant over the paving surface.

5.5 Paver Units
Rectangular 8-cm-thick pavers with compressive strengths of 55 MPa and conforming to International Concrete Paving Institute (ICPI) requirements and American Society of Testing and Materials (ASTM) standards were specified.

5.6 Production and Installation
The contractor was to be either experienced in paver installation or get trained under direct supervision by experienced personnel. While mechanical installation was encouraged, it was not required.

5.7 Mock-Up
The contractor was to install the pavers in a 20- by 20-meter, mock-up area in the presence of an ICPI-certified expert. The mock-up would be constructed using the approved pavers under supervision of an ICPI-certified inspector.

5.8 Acceptance Criteria
Profile and variation tolerance of the CTB, maximum/minimum bedding sand thickness, and final paver surface variation were also specified.

6. BIDDING AND CONTRACTOR SELECTION

Separate contracts were awarded for the wick drain/surcharge program and the yard construction. Because the equipment for wick installation was not available in Panama, the work was bid primarily to U.S. contractors who had the necessary experience.

Bidding documents for the yard construction included four alternative pavement cross sections. The $6 million project, which included water lines, sewers, electrical vaults/duct banks, and light pole foundations, was bid to three competent local contractors. After verifying and evaluating the bid, the contract was awarded to the contractor who performed most of the Phase I paving at MIT. After awarding the contract, the design team worked closely with the contractor to fine-tune the design, optimize costs, and create a work plan that would guarantee the success at this first-time project in Panama.

7. QUALITY ASSURANCE AND INSPECTION PROGRAM

Aware of the challenges of a first-time, large-scale CBP installation in Central America, design engineers included a detailed quality assurance program in the project's specifications. Key elements of this program included the use of ICPI- and ASTM-certified pavers and installation by an ICPI-certified contractor with experience on at least five similar port projects.

Given that heavy-duty CBP construction was a novelty in Panama, the requirement for the use of ICPI-certified pavers meant that all pavers for the 8-hectare yard project would have to be imported from overseas. Shipping costs alone would pose a significant negative impact to the overall project cost. Therefore, working with an experienced local concrete masonry plant, the contractor proposed production of the pavers in Panama following ASTM and ICPI standards. The design team guided the local plant through the procurement of block forms from a European manufacturer and made recommendations of modifications necessary for local production. Paver lots were tested for compliance with ASTM standards in a local lab. Testing results from each lot were reviewed and approved by the design engineering team, which was retained to assist the in-house construction management team during the construction.

Although familiar with CBP, the contractor did not have an ICPI-certified installer and had not performed any large-scale CBP construction projects. In lieu of the certification requirement, the design team recommended that the contractor procure the services of a foreign CBP installer expert that met the certification and experience requirements. The CBP expert would assist the contractor through the construction of the mock-up area, would serve as troubleshooter, and would perform inspections at critical points in the installation.

Prior to construction, the owner's construction management team designed reporting and recording documents to be used during the construction by the contractor and by the inspection team. Reporting documents included an effective grid system that subdivided the 8-hectare yard into manageable 10- by 10-meter-square sublots. The contractor was required to submit CTB thickness and density testing information on the grids for review. Sublots were selected by the engineer on a random basis for field density testing. On the grid, the contractor was required to submit the date of the testing, strength achieved at 7 days and 14 days, and the percentage of compaction achieved.

In addition to close coordination with the contractor through weekly meetings, the overall success of the quality assurance program was enhanced by prompt responses from the designer's engineering team.

8. CONSTRUCTION PROGRAM

Construction of the ground improvements began in 1996. Obtaining the needed surcharge materials at a reasonable cost was a challenge. Trucking large quantities of fill soils from land-based sources would have taken too long. Besides, soils (such as gatun) could not be handled in rainy weather. Hence, the soils needed for filling and surcharging the site were obtained by mining sands from the sea bottom from a source 15 km away from the site. Using a suction hopper dredge, nearly 400,000 cubic meters of sand was picked up and deposited at the site. Significant cost savings were achieved by combining some of the berth dredging, which was disposed at sea, with the sand hauling. Ultimate settlement varied between 0.5 and 1.2 meters. For awhile, MIT used the surcharged areas for temporary stacking of empty containers, which provided additional loads for consolidation. The surcharge program was maintained and settlement monitored for two years.

Following consolidation, the surcharge was spread across the yard to achieve the desired 60-cm subbase section.

After placing, grading, and compacting the sand in layers, the contractor proceeded to place the crushed rock (mixed) base. This material proved to be economical and resulted in high CBR values. The mixed base, as well as the CTB, was produced on site in a pug mill. The proportions were established by laboratory testing by the geotechnical consultants as part of their investigations. A conventional asphalt paving machine was used to place the CTB in layers and compacted by vibratory rollers to achieve the desired field densities. Figure 4 shows construction of the CTB layer.



Figure 4. CTB placement and compaction.

Nonadherence to the specified CTB tolerances produced adverse impacts to the overall construction program. In many areas, the CTB elevations were above or below the specified +/-6-mm requirement. Areas that were too high were corrected via mechanical grinding. Depressions were corrected by applying a minimum 5-cm layer of a fine aggregate asphalt mix. The need for extensive CTB repairs caused significant delays.

Securing an approved sand source for the bedding sand proved to be another problem for the contractor. The existence of numerous sand sources in Panama led the contractor to underestimate the intricacy of meeting the degradation testing requirements. Over a dozen sand samples, including natural and manufactured sands, were unsuccessfully tested for degradation compliance. Most samples produced undesirable quantities of fines, particularly in the 200-sieve range, after the wearing test. After balancing the gradation and degradation requirements, a local sand was approved for use as bedding and joint sand. This sand was washed to remove all the fines. Approval of one sand source for bedding and joint sand activities simplified the construction and eliminated the need for multiple stock piles.

Approximately 40 percent of the 3.6 million paving blocks needed for the container yard was produced in the United States and shipped to Panama to get a head start. The remaining pavers were produced by the local plant. It took several trial mixes and manufacturing changes to produce the high-quality pavers consistently. Local pavers had rougher surfaces than the imported counterpart yet they consistently achieved higher than specified compressive strengths and were produced at a fraction of the cost. Prior to the installation of the pavers, a transition slab was constructed along the existing yard to guarantee a uniformly level edge and consistency of the paver laying pattern. A 20-by 20-meter, mock-up area was constructed using the approved pavers under supervision of a U.S. ICPI-certified inspector. The mock-up served as the standard for construction throughout the project. The contractor chose to install the pavers mechanically with manual adjustment as needed. An installation rate of 500 square meters per day was reached.

However, gap tolerances from palette to palette were ignored and significant time was expended to achieve uniformity in the laying pattern by hand placing.

Following the CBP installation, a clear urethane sealer was used to reduce loss of the joint sand and prevent water infiltration through the paving system. Figure 5 shows the completed Phase II improvements project.

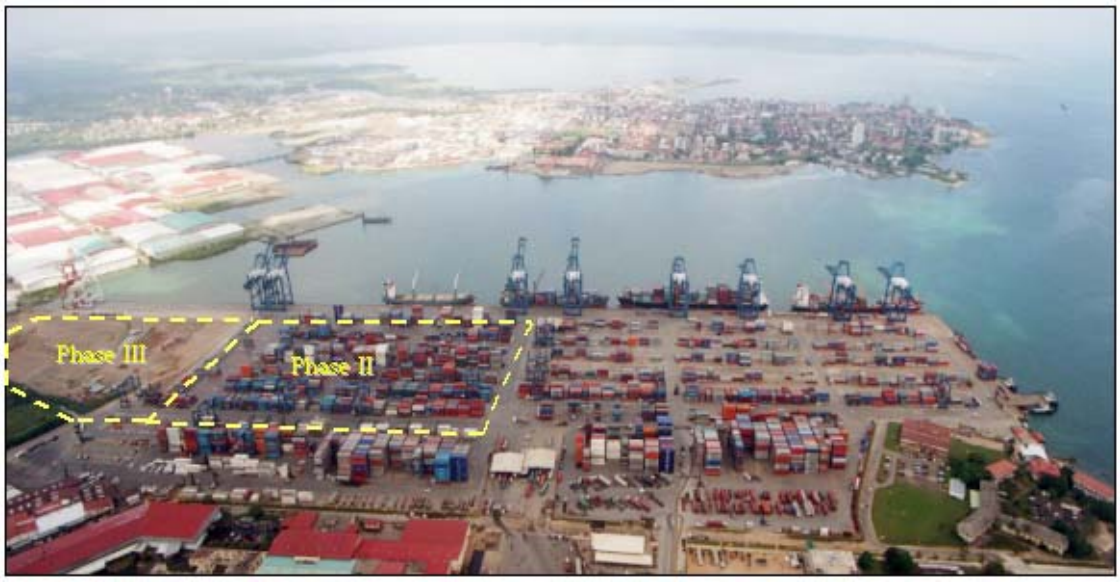


Figure 5. Existing MIT yard and completed phase II improvements.

9. LESSONS LEARNED

The overall design and construction of the Phase II improvements project proved to be a huge success. However, despite considerable efforts expended by the designers to anticipate the needs of this first-time, heavy-duty CBP procurement project in Panama, the project was not devoid of challenges. Some of the lessons learned are summarized below.

9.1 Importance of Geotextile

The original design pavement section called for the use of a woven geotextile above the CTB and below the bedding sand. The geotextile requirement was relaxed due to concerns of its placement during the rainy season. Specifically, the concern was that if the bedding sand was disturbed by rain prior to the laying of pavers, it would be almost impossible to remove and reuse the geotextile without causing rupture of the fabric. Thus, substantial quantities of the geotextile would need to be supplied. As a result of removing the geotextile requirement, several local failures have been caused by the loss of bedding sand through CTB cracks. As local failures are repaired, the geotextile is being placed by the owner. The concern for the construction of the geotextile layer during the rainy season could have been mitigated by establishing a maximum distance between the screeting and paver laying operations within the specifications.

9.2 Colored Pavers

Project specifications called for the use of yellow-colored pavers to create permanent striping of RTG tracks and stop signs throughout the yard. The dull nature of the colored pavers supplied on the job provided minimal contrast to their standard sand colored counterparts. It was also very difficult to get the colored pavers placed right to form the straight lines required for RTG tracks. Therefore, the goal of eliminating paint striping was not achieved. At present, it is doubtful if color pavers can be used successfully as the sole striping technique.

9.3 Contractor Training and Controls

The CBP construction project proved to be a challenge even for an experienced roadway contractor. A key aspect that supported the success of the project was the requirement of mock-up areas and of international experts, which imparted substantial training to local crews.

Failure to meet the CTB placement tolerances caused significant delays in the overall construction program. Although several areas had been identified as deficient, the contractor was allowed to continue on the installation of CTB in new areas prior to implementing appropriate remediation measures. This led to the creation of a random patchwork of good and substandard CTB segments, some of which would later need to be removed. As the heavy rains appeared, several large pools of water were created amidst the acceptable CTB segments. Therefore, additional pumping operations were needed to remove stagnant water prior to constructing the CTB in these areas. Significant time and resources would have been conserved if tighter controls were placed on the contractor during the CTB construction phase.

9.4 Predesign Testing

A large part of the success of this first-time project in the Republic of Panama can be attributed to the extensive predesign testing program undertaken by BERGER/ABAM. Most of the last-minute difficulties attributed to the procurement of a suitable source for the bedding and joint sand could have been eliminated had these been included in the predesign testing program.

10. CONCLUSION

The holistic design approach used in the project, coupled with experienced staff and close coordination between designers, experts, and contractor, yielded a very successful pavement procurement project. The Phase II paving work began in early 2000. Change orders where minimized and high quality was maintained through close monitoring of the project elements and prompt resolutions to unforeseen field problems. Work was completed in June 2001. Although the expected completion date was missed, all the quality standards established for the program were successfully met.

The newly constructed container yard has expanded MIT's total prime stacking yard area to 40 hectares. Strict controls set in this project have yielded a uniform, sound, and well-performing pavement meeting the owner's expectations. The terminal has far exceeded original projections and is now handling more than one million TEUs per year. The new MIT yard has the marked distinction of being the first heavy-duty CBP construction in the Republic of Panama.

11. ACKNOWLEDGEMENTS

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Biography

Name : V.K. Kumar

Education : BS, University of Madras/1967/Civil Engineering
MS, University of California/1968/Structural Engineering
MArch, Virginia Polytechnic Institute/1972/Building Systems

Registration : 1979/Civil and Structural Engineer, Washington
1985/Civil Engineer, Florida

Experience : V.K. Kumar has over 25 years of planning, engineering, and construction experience in ports and maritime terminals worldwide. As vice president and department head, he has supervised the design and construction of several new container terminals and upgrade of existing terminals in the United States, Asia, South America, and Central America.

His applicable project experience includes:

- Project principal for the planning, program management, design, and construction of the Manzanillo International Terminals in Colon, Republic of Panama; the $200 million, 1 million TEU/yr dedicated container terminal included 1,250 meters of container wharf, 225 meters of general purpose wharf, 50 hectares of heavy-duty paving, entry facilities, shops, offices, and berth/channel dredging
- Project principal for planning, permitting, and preliminary engineering of a world-class container terminal to be developed along Savannah River in South Carolina, for a private port developer
- Project manager for feasibility study, detailed design, and construction management for a privatized container and break/bulk terminal in Merak, Western Java, Indonesia; project included site reclamation, a 350- by 45-meter breakwater pier, a 200-meter-long barge berth, a 300-meter-long container berth, container crane interface, 16 hectares of container stacking yard, a 20,000-square-meter pulp and paper warehouse, entry/office complex, and all the associated infrastructure
- Project principal for value engineered redesign of a 220,000-square-feet, pile-supported deck for Bath Iron Works' new land-level transfer facility in Bath, ME; project also included construction engineering of landing grids and design of a trolley/rail system for the safe mooring of a dry dock next to the deck in support of ship building activities
- Project principal for evaluation and upgrade of existing facilities and master planning of new facilities for San Vicente International Terminals near Concepcion, Chile; upgrade will involve new rail-mounted container crane operations, mobile harbor crane operations, and new terminal configuration for increasing cargo throughput for the newly formed terminal company

Project principal for feasibility study, permitting, and preliminary engineering of a dedicated container terminal on a dredge spoil island in Texas City, TX, for a private developer