DESIGN AND CONSTRUCTION OF CONCRETE BLOCK PAVEMENTS FOR HEAVY DUTY RAILWAY FREIGHT TERMINAL

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SUMMARY

As a part of the vast expansion of its industrial and passenger railway networks, the Israeli Railway Authority has recently completed the industrial railway line to Ramat Hovav, south of Beer Sheva, in the Israeli Negev. At the end of this line, a freight terminal was designed to accommodate the handling of industrial goods and containers as well as hazardous waste materials. The main operational facility of the terminal consists of a long open paved apron, 65 m. wide, with a total area of 30,000 m^2. The apron was designed to be based on the natural silty clay (loess) subgrade soil.

The original pavement design solution for the terminal apron specified a 95 cm thick flexible asphaltic pavement, consisted of 45 cm of bituminous concrete layers and 50 cm of unstabilized base and subbase courses. Due to the sensitivity of the asphaltic surface to the embedment of containers base-corners in hot climates, to the spillage of fuels and oils, and also due to some logistical limitations, an alternative Concrete Block Pavement (CBP) structure was suggested and considered. Since CBP is in many cases unfamiliar to the administrative and engineering decision makers, an extensive engineering effort was made to present the technology to the key officials involved in the project. Finally, following a detailed engineering and economical comparison between the two alternatives, a decision was made to convert the flexible structure to concrete block pavement.

Technically, the pavement conversion was made by using local layers equivalencies, mainly to convert the upper asphalt structure to concrete blocks and stabilized base courses. The total thickness of the final suggested CBP structure was also 95 cm, consisted of: 10 cm 10/20 rectangular paver blocks, 3 cm bedding layer, 32 cm cement stabilized base courses, and 50 cm of granular base and subbase courses. A geotextile fabric was placed above the stabilized base in order to avoid filtration of the bedding sand down to lower layers. Due to the handling of hazardous materials the surface of the completed paver layer was sealed by a suitable polymeric compound. The construction of the terminal CBP apron was started in July 2003 and terminated in March 2004.

During construction, a very strict quality control program was applied. Among the routine testing for material quality & composition and for layers density, special tests were performed

for the unconfined strength of the cement stabilized material, and filtration (permeability) test of the sealed surface. The operation of the terminal was initiated in May 2004. During and after two years of full operation, the apron has exhibited a very good level of service, with complete satisfaction of the users.

1. PROJECT DESCRIPTION

During the last ten years, Israel has experienced a major development and expansion of its industrial and passengers railway networks. As a part of this expansion, the Israeli Railway Authority has recently completed the railway line to the industrial city of Ramat Hovav, south of Beer Sheva. At the end of this line, a freight terminal was designed to accommodate the handling of industrial goods and containers, as well as hazardous waste materials.

The main operational facility of the terminal consists of a long open paved apron, 65 m wide and 460 m. long, with a total area of about 30,000 m^2. The apron was designed to handle the storage and movement of 20,000 containers per year which will be piled in three storey formations. The containers mobility will be carried out by heavy fork lifts, weighing 90 tons.

The geo-engineering formation of the of the top subgrade soil in the Ramat Hovav area is characterized by the "Negev Loess", which can be described as a low plasticity silty clay (classified as SM-CL according to the Unified System or A-4 to A-6 according to AASHTO method).

2. ORIGINAL PAVEMENT DESIGN

The original pavement design solution for the terminal apron specified a 95 cm thick flexible asphaltic pavement (T&M 2000). The design was carried out according to the "Guidelines for Pavement Design in Ports" (T&M 1999) which was developed for the Israeli Ports Authority. This method is mainly based on the Spanish guidelines for the design and construction of port pavements (Spanish Code 1994).

Using the new pavement design method parameters: "E_1" for the subgrade Soil, and "A" for the traffic load category, the following pavement structure was determined and assigned for the terminal apron:

Aphaltic Wearing Course	**-**	**5 cm**
Five Layers of Asphaltic Base	**-**	**40 cm**
Non Stabilized Base Course	**-**	**25 cm**
Non Stabilized Subbase Course (Type A)	**-**	**25 cm**
Total Pavement Thickness	**-**	**95 cm**

This design was approved by the Railway Authority, and the construction phase of the project was initiated in the middle of 2003. At the end of that year, the earth works, and the bottom granular courses of the terminal apron (50 cm. thick) were constructed and completed within the frame of an initial contract. The top asphaltic structure of the apron was planned to be executed under different contract.

3. PAVEMENT CONVERSION

3.1 The Behavior of Asphaltic Pavements in Port Applications

Barber and Knapton (1980) stressed the unsuitability of asphaltic surface courses for ports. They stated that three characteristics of the asphaltic mix have resulted in an overall poor performance in port applications:

1. The stiffness, or strength, of the bituminous materials decreases as the temperature rises.
2. The stiffness of a bituminous mix decreases as the loading time decreases (slower vehicles, static loadings, etc).
3. Surface oil pollution (oil and fuel spillage) slowly dissolves the bituminous binder, leaving more susceptible to scuff and frost attack.

It was found that the common hot asphaltic applications used for ports in the UK were too soft to carry the large wheel loads, high contact stresses, and low vehicle speed associated with container handling areas.

Iskander (1992) presents the inferior performance and damages of asphaltic pavements in container terminals in Indonesia: The top asphaltic layers did not withstand the high static loads of containers stocks, and also failed under the dynamic and impact loadings developed during the handling of containers using edge loaders. Also spillage of fuels and oils caused the weakening of the top asphaltic layers. Similar findings were reported during the last 25 years in the literature (Umeda et al. 1996, Luidens and Van Hees 1996, Van Hees and Arcadis 2000, and others).

The major argument against the use of asphaltic pavements in port applications is the embedment of container corners in the top asphaltic layers (see Figure 1):



Figure 1. Prints of the embedment of container corners into the asphaltic top layer (Haifa Port 2004)

The load of the container is transferred to the pavement surface by its four base corners only. Usually the base corner dimensions are 16x18 cm, and it exceeds the container floor down by only 13 mm. A pile of three containers (weighing 20 tons each) produces a bottom corner load of 15 tons, or stress of 52 kg/cm^2 on the pavement surface. This stress is extremely high causing the embedment of the corner into the asphaltic surface due to slow creep deformation. This mechanism intensifies in hot climates. The container structure is designed to be supported on its base corners only (not on the floor or walls), thus when the embedment deformation exceeded the thickness of the bottom corner (13 mm.) the container floor and wall structures are laid directly on the pavement and the high loadings is directly transferred to the bottom container wall. In many cases this leads to the collapse of the container. This phenomenon can not occur in hard and rigid surfaces, such as rigid concrete pavements or segmented concrete pavements (CBP), as can be seen in Figure 2.



Figure 2. Slight surface damage due to container corner loading on Concrete Block Pavement (Haifa Port 2004)

It can be concluded that asphaltic pavements are usually unsuitable for industrial surfaces which accommodate intensive, detrimental and abrasive traffic, spillage of fuel and oils, and high concentrated static loading (i.e. port application and container terminals).

3.2 The Concrete Block Pavement Alternative

Due to the above mentioned sensitivity of the asphaltic surface to the embedment of containers base-corners in Negev hot climate, to the expected spillage of fuels and oils, and also due to some logistical limitations, an alternative Concrete Block Pavement (CBP) structure was suggested and considered. Since CBP is in many cases unfamiliar to the administrative and engineering decision makers, an extensive engineering effort was made to present the technology to the key officials involved in the project. Finally, following a detailed engineering-economical comparison between the two alternatives, a decision was made to convert the flexible structure to concrete block pavement. The rigid concrete pavement alternative was totally rejected due to its most expensive cost, as compared to the two other types of pavement. It should be stressed that this final decision was made quite late, when the bottom granular layers of the apron pavement were already paved.

4. CONCRETE BLOCK PAVEMENT DESIGN

The following considerations and constraints were involved in the process of converting the flexible asphaltic pavement to CBP:

1. The designed structure of the flexible pavement, as determined using the Israeli Port Authority method, will be served as the basis for the CBP structure. This was needed for the approval and participation of the original pavement designer.
2. The pavement conversion should take into account the existing bottom granular layers that have already been paved.
3. The pavement conversion will be made using the layers equivalencies (conversion factors) that are accepted in the local paving technology. These factors are presented in Table 1:

Table 1. Locally Accepted Layers Equivalencies used for the Pavement Conversion

Layer and Material	Thickness of the layer equivalent to 1.0 cm of Hot Asphaltic Concrete
Concrete Pavers	0.8
Cement Stabilized Base Course	1.2
Asphaltic Base Course	1.2
Non-Stabilized Base Course	1.5
Type A Subbase Course	2.0
Type B Subbase Course	2.5
Bedding Sand	∞*

* The bedding sand has no structural value

Accordingly, the following concrete block pavement structure was designed, as equivalent to the original flexible asphaltic pavement:

Rectangular Concrete Pavers (10/20 cm)	**-**	**10 cm**
Bedding Sand	**-**	**3 cm**
Geotextile Fabric	**-**	**---**
Cement Stabilized Base Courses (4%)	**-**	**32 cm**
New CBP Structure	**-**	**45 cm**
Non Stabilized Base Course	**-**	**25 cm**
Non Stabilized Subbase Course (Type A)	**-**	**25 cm**
Already Paved Granular Layers	**-**	**50 cm**
Total Pavement Thickness	**-**	**95 cm**

A geotextile fabric was designed to be placed on top of the cement stabilized courses, in order to prevent the filtration of sand from the bedding layers down to the stabilized layers, and thus preventing the loss of support to the paver layer. Also, a polymer compound was specified for application on top of the pavers in order to provide initial and sealing of the pavement. This was done in order to prevent water and hazardous liquids to penetrate through the CBP layers.

5. CONSTRUCTION AND QUALITY CONTROL

The construction of the top CBP structure was started in December 2003 and was made according to local standards and specifications. Very strict Quality Control program was applied during all paving phases. Figures 3 and 4 describe some phases during the installation of the geotextile fabric, laying of the bedding sand and pavers.



Figure 3. Preparing the geotextile fabric and bedding sand for continuous paver laying



Figure 4. A close-up detailing the paver laying

Special attention was given to the production and paving of the stabilized base courses. Table 2 summarizes the basic indicative and engineering properties of the stabilized base mixture during production in the quarry:

Table 2. Ranges of Stabilized Base Mix Properties during Production (9 Tests between 21.12.03 to 5.1.04)

Gradation								
Sieve, mm	**37.5**	**25**	**19**	**9.5**	**4.75**	**2.0**	**0.42**	**0.075**
% Passing	100	82-92	73-81	57-65	41-52	29-36	11-17	5.8-9.5

Moisture Content, %	**Sand Equivalent, %**	**Maximum Density, kg/m^3**
5.5-7.7	52-67	2154-2180

The stabilized base mix was produced in a pug-mill. Crashed graded aggregate fractions were fed to the pug-mill by controlled and calibrated streams from the storage bins. Controlled quantities of water and cement were fed directly to the pug-mill during mixing. The final mix was dumped to a track and immediately hauled to the site. Spreading of the stabilized base mix was done using an asphaltic paver (finisher). Field density tests were performed after compaction using a nuclear gauge. Within 60 field tests the density degree of the compacted base course ranged between 99.5-101.7%. Twenty eight days after construction, 10 cores (100 mm diameter and 100 mm height) were drilled from the stabilized base surface and tested for shear strength. The results ranged between 7.3-16.5 MPa, indicating high shear strength but wide variability.

With respect to the strict criteria for sub-soil contamination, set by the Ministry of Environmental Quality, the final CBP surface was tested for Water Filtration after sealer application. The test was performed according to the procedure recommended by Madrid et al. (2003). The testing setup is shown in Figure 5. The results indicated that the sealed CBP exhibited low filtration conditions, as reflected by a Coefficient of Permeability in the range of (2.8-5.2) x 10^{-5} cm/sec. The rate of filtration will be monitored periodically in the future.



Figure 5. Performing Water Filtration Test on the final CBP surface

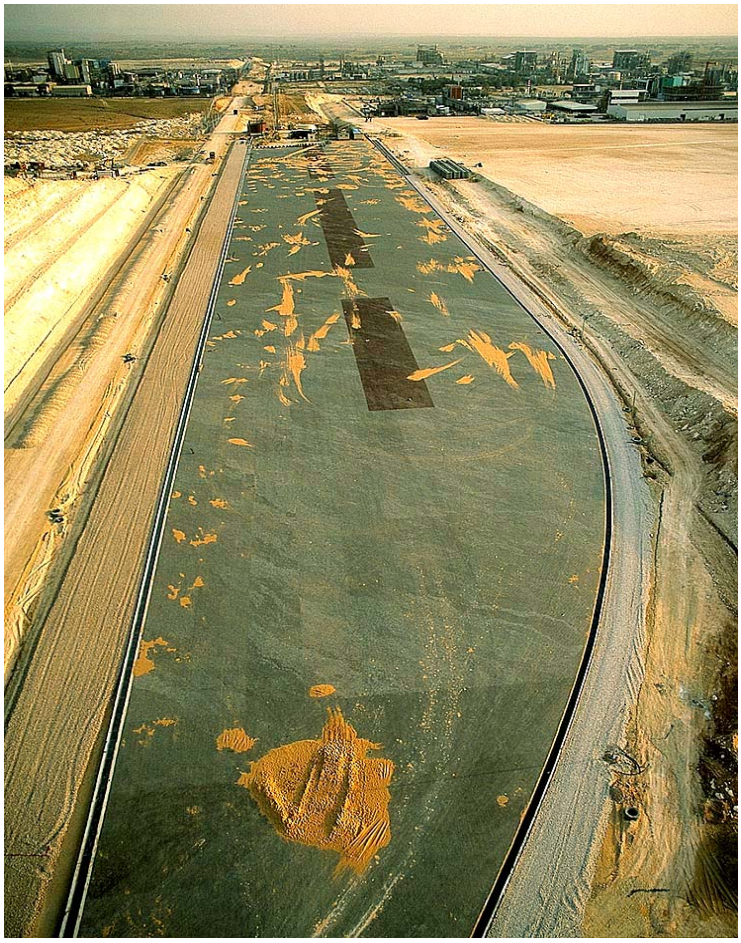
6. PROJECT COMPLETION

The construction of the terminal CBP apron was started in July 2003 and terminated in March 2004. The operation of the freight terminal was initiated in May 2004. During and after two years of full operation, the apron has exhibited a very good level of service, with complete satisfaction of the users. Figures 6 through 8 present the overall view of the CBP apron during the completion stage:





Figures 6 and 7. Overall view of the CBP apron during the completion stage



Figures 8. Overall view of the CBP apron during the completion stage

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8. ACKNOWLEDGEMENTS

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