EXPERIENCES OF 15 YEARS OF CBP IN THE PORT OF HELSINGBORG, SWEDEN –
PART 2: Refurbishment of an existing CBP by laying a top layer of reinforced asphalt

By Mr Göran Hammarskjöld
Technical Manager
Port of Helsingborg
P.O. Box 821
SE-251 08 Helsingborg
Sweden
Telephone number: + 46 – (0)42 10 63 00
Facsimile number: + 46 – (0)42 24 31 13
E-mail address: g.hammarskjold@port.helsingborg.se

ABSTRACT
The CBP of the container terminal of the port of Helsingborg, Sweden, has got severe damages and settlements after the first 15 years of operation mainly due to a too weak foundation design.

At the Cartagena conference in 1998 Part 1 of this paper was presented where an extensive test programme for a refurbishment project of the 100.000 m^2 was discussed based on a recycling concept.

The board of the Port did however not approve of the cost of the proposed refurbishment project based on the recycling programme so a new concept must be identified. The costs were regarded to be too high. After several study tours to other European container terminals it was decided to have a paving layout consisting of CBP within the container stacking areas and asphalt paving within the traffic areas.

The paving of *the stacking areas* was obtained by removing both the CBP and the subbase and replacing it with a new CBP on a foundation of lean concrete.

In order to minimise the costs for the refurbishment of *the traffic areas* the existing CBP had to be kept and not removed. The idea came up of placing a steel reinforced asphalt paving in two layers on top of the existing CBP.

Hereby the costs were reduced from about 55 USD/m^2 for the recycling project to about 19 USD/m^2 for the modified project. The board accepted this budget for the refurbishment project.

At present a total refurbished area of about 15.000 m^2 has been in operation for two years including two full cold winter season and one very hot summer season. Experiences have so far been very good and the truck drivers are very pleased with the end product.

It has however clearly turned out the importance of extremely careful performance during the various phases of undertaking the asphalt refurbishment works on top an existing CBP.

1. BACKGROUND

The city of Helsingborg is located in the south part of Sweden where the strait of Öresund has its narrowest section of 3 n.m. to Helsingor, Denmark.

The first part of the modern port was built in 1832 when two breakwaters were constructed. A minor part of these structures can still be seen. The ferry connection between Helsingborg and Helsingor, Denmark, is the busiest ferry traffic in the world between two ports of different countries.

The Port of Helsingborg has developed to be the second biggest port of Sweden. It is a multipurpose port with an annual turnover of about 10 million tonnes (1999).

The container port, the West Harbour, has a terminal area of about 100.000 m^2. His Majesty the King Karl XVI Gustav inaugurated the terminal on a sunny day in May 1985. This was the first terminal area for heavy operation of this size in the Sweden with a CBP.

The container terminal has been in operation for about 15 years and a great deal of experiences have been obtained from CBP. They were presented at the Cartagena conference and are summarised in brief also in this paper.

The main problem of the CBP has been the severe settlements which were found out to be a function of a too weak original design of the substructure.

2. THE CONTAINER TERMINAL OPERATION SYSTEM

The terminal was originally designed as a ro-ro terminal. However it is to-day mainly used for lo-lo operations. The annual turn-over is about 70.000 TEU:s.

The horizontal transportation within the terminal is done by FLT implying an axis load on the pavement of more than 85O kN. Terminal tractors and trailers are used for transportation between the different terminals of the port.

3. ORIGINAL DESIGN OF THE CBP IN THE CONTAINER TERMINAL

The port was built up of reclaimed sand dredged from the strait of Öresund outside the port. All quays were of sheet piling design. The fill was compacted by a 13 tonnes vibrating roller making more than 6 overpasses. No depth compaction was undertaken.

The paving was decided to be of CBP type mainly based on a study tour to the ECT Terminal in Rotterdam.

The substructure on top of the reclaimed sand was, mainly due to economical reasons, limited to

- 300 mm of granular layer
- 30 mm of bed sand
- 100 mm concrete blocks.

The concrete blocks were of both Uni-coloc and SF-block of 100 mm types with a concrete strength of K60 (= 60 MPa after 28 days). The two different types of blocks were used due to limitations in production capacity at the two factories available at that time.

4. EXPERIENCES OF THE CBP AFTER 15 YEARS OF OPERATION IN THE CONTAINER TERMINAL

The truck drivers complained to the Workers Safety Committee about an unacceptable working situation due to the severe settlements in the paving only a short time after the starting of the operations in 1985. An investigation was undertaken which showed that the working conditions were not suitable in the driving cabin of the FLT .

Others problems were also identified of more technical character e g cracks in the CBP, difficulties to undertake modifications in the terminal layout. They are further described below.

4.1 Settlements

Severe settlements developed only after a short period of time in the paving. These settlements were of two types

1. general settlements in the reclaimed sand fill
2. settlements due to the terminal operations

The *general settlements* in the reclaimed sand fill developed unevenly within the terminal area. It appeared that both the differences in the fill thickness and variations in the fill material had caused these settlements. Of course this had nothing to do with the CBP.

As previously mentioned no depth compaction was undertaken of the reclaimed area except with a 13 tonnes vibrating roller. We to-day estimate that the general settlements in the sand fill are fully developed.

The *terminal operations* caused more difficult settlements due to their local character. After a while one could easily identify the pattern of the terminal operations by the FLT:s if one studied the settlements in the paving. Frequently used driving lanes and braking spots in front of vehicle loading points and container stacks gave the CBP severe concentrated damages.

These damages were not a function of the concrete blocks themselves but were caused by the too weak design of the substructure under the blocks.

The settlements in the container terminal were of such a magnitude that a major refurbishment programme had to be undertaken.

4.2 Cracks

After the first period of operation in the autumn of 1985 long cracks were observed in the paving. These cracks turned out to be caused by the wheels of the terminal trailers when the rubber tyre had been torn off. It also turned out that these cracks only developed during the first period of operation after the inauguration of the terminal.

Apparently the concrete of the individual block did not have the adequate concrete strength when the FLT-operations was allowed.

As a consequence we to-day have a **Port of Helsingborg CBP-policy** that concrete blocks are, if possible, bought and manufactured six months before laying.

4.3 Storm water drainage

The storm water drainage system was built of the open drainage type with corner steel bar reinforcement at the opening. It has been found that this type of ducts can not withstand the load of the FLT wheels in the container terminal.

As a **Port of Helsingborg CBP-policy** storm water drainage is to-day handled the traditional way of giving the top surface relevant service falls towards ordinary gullies

4.4 Alterations of the terminal layout

The Operations Department has during the passed 15 years from time to time requested alterations in the container terminal layout due to changes in the traffic. In a great number of these cases it has been necessary to undertake works in the CBP.

It has been found that it is almost impossible to obtain a good connection and avoid a bump to neighbouring non-rebuilt areas of the CBP if shaped concrete blocks were used.

As a **Port of Helsingborg CBP-policy** we to-day only use rectangular blocks.

At the first major modification projects in the container terminal we tried to re-use the old blocks. It appeared however that the individual sand grains, from the sandfill in the CBP joints, were so firmly attached to the blocks that the blocks could not be replaced at the proper distance. Hard waterjet flushing of the individual concrete blocks was not sufficient to get rid of the sand grains to the required extent.

As a **Port of Helsingborg CBP-policy** we therefore buy new concrete blocks in refurbishment projects which of course is very popular among the concrete block suppliers.

New operations layout often requires new layout for e. g. piping and lightning in the terminal.

As a **Port of Helsingborg CBP-policy** new major terminal projects are provided with a grid system of empty pipes in the subbase where additional cables can be placed at a later stage. Despite the extra cost during the implementation stage of the project our experience is that we have avoided many bumps and the truck drivers are happy.

5. ALTERNATIVE CBP REFURBISHMENT DESIGNS OF THE CONTAINER TERMINAL

As mentioned above it was realised that a major refurbishment project of the CBP had to be undertaken in the container terminal due to the severe settlements. Various methods were studied and tested. This was presented at the Cartagena conference.

In the first step of evaluation completely new paving structures were studied based on either CBP- or asphalt design. It was however found that the costs for a complete refurbishment project according to these alternatives would be very high, 75.- USD/m^2 for the CPB-alternative and 95.- USD/m^2 for the asphalt based alternative. The Board of the Port refused to accept either of these solutions.

Therefore in the second step the idea of recycling came up. Firstly vast tests of reusing the blocks in a new paving showed us the great difficulty of getting rid of all sand grains on the edges of the individual old blocks from the sandfill of the joints. So this solution was abandoned Therefore it was tested to use the existing concrete blocks after crushing as an aggregate in the lean concrete of the substructure.

In Cartagena this refurbishment project was presented based on several full-scale tests. Though the tests gave sufficient technical results and the costs for this alternative refurbishment project was reduced to about 54.- USD/m^2 the Board of the Port also rejected this project due to the costs.

Therefore a less expensive solution had to be found. New ideas had to be tested with a new approach to the problem. So the life cost aspect was taken into consideration.

All the previous solutions were based on the philosophy of doing a high quality refurbishment project with full bearing capacity for the planned terminal operation systems with only small future maintenance cots. An alternative approach would be to undertake a refurbishment project with somewhat reduced bearing capacity where higher maintenance costs could be accepted in the future.

A third step of the approach to the refurbishment project was therefore to find a feasible solution where the existing paving should not be replaced. Additional strengthening of the paving should be obtained by placing new layers on top of the existing CBP. Hereby the old CBP was theoretically regarded to be included in the substructure. As this would imply a weaker design than the previously studied alternatives this must be done in such a way that future refurbishment works could be done to the lowest possible costs.

It was understood, from budget limitation point of view, that this solution could not be used in the entire terminal but should be tested in full scale in those parts of the terminal where the most severe settlements were located.

This project is further described in this paper.

6. REFURBISHMENT OF 15.000 M^2 OF THE CBP AREA

Two main alternatives were regarded as possible top layers in the low-cost refurbishment project:
- CBP
- asphalt.

The first mentioned alternative was discussed with some contractors who had the experiences from other projects where a new concrete block layer had been placed on top of an existing

CBP. Their common experience was not positive if the final surface level should be kept as close to the original levels as possible. This had lead to a too thin bed for the new CBP on top of the old CBP which had caused severe settlements and movements in the new paving already after a short period of time.

Therefore the alternative of laying asphalt on top of the existing CBP was further studied. In order to improve the bearing capacity of the asphalt layer and to better withstand the shear strength of the turning wheels of the FLT it was considered that relevant additional measures had to be taken.

However our experiences, from other stacking areas in the port, of the intrusion problems from container corners in a paving surface of asphalt made us doubtful about an asphalt solution in the staking areas. **A suitable alternative could be to lay an asphalt refurbished paving in traffic areas and CBP within the container stacking areas.**

This idea was further encouraged when we visited the Roland Umslag terminal in Bremen, Germany, and the container terminal in the Port of Lisbon, Portugal. This appeared to be a good solution in these two terminals.

Service facilities could be placed in the asphalt areas and the CBP need not to be touched in connection with any layout alteration works. The disadvantage is the reduced flexibility of the terminal layout.

6.1 Traffic areas refurbished with reinforced asphalt

Steel net reinforcement of asphalt paving has been used in Sweden and Norway for a couple of years. The basic idea was to improve the performance of the paving in connection with the thawing of frozen soil and to improve its bearing capacity.

This method has been used for more than 25 years in Sweden but not until 1989 it has been used to a greater extent when a method was developed which eliminated the problems in connection with the laying of the asphalt layer proper.

The system of reinforced asphalt paving has now been used in larger scale for a number of years e g on roads, airfields and in heavy vehicle terminals. So far the experiences show good performance in the requested aspects as well as reduced cracking of the paving as well as reduced rutts in the paving from heavy traffic.

6.1.1 Paving with reinforced asphalt

In the first step local settlements and pot holes of the surface of the existing CBP had to be filled up with levelling course of a minimum thickness of 20 mm to obtain an even surface.

The prefabricated steel reinforcement nets were placed on the levelled surface. The mesh size can vary between 50 and 125 mm. In our case we chose 75 mm and a steel rod diameter of 5 mm. See Photo 1 below.

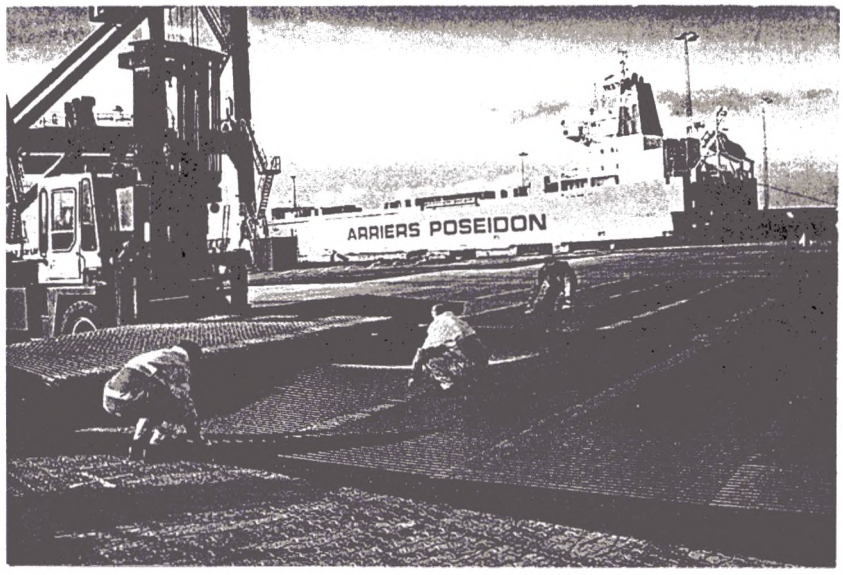


Photo 1. Laying of prefabricated steel reinforcement nets

Initial alternative tests using plastic fibre nets showed less positive results.

Special attention was paid to the joints between the individual nets. This was arranged in such a way that no threefold or fourfold thickness of steel bars was obtained. See Photo 2 below.

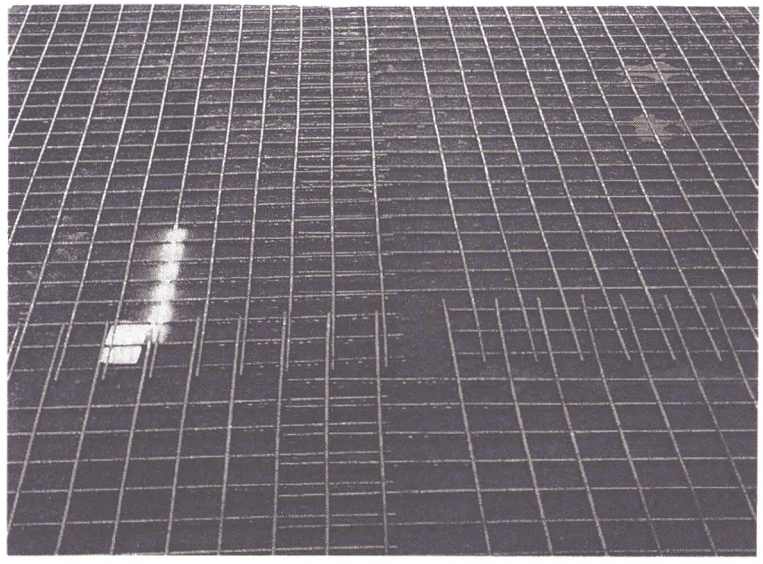


Photo 2. Joints between the reinforcement nets

The entire area with the reinforcement nets was sprayed in two steps with tack-coat to obtain good adhesion with the asphalt.

The asphalt was thereafter lain in two layers with the bottom layer of 40 mm. The reinforcement was placed in this layer. The top layer has a thickness of 50 mm. The stones of the asphalt mixture were maximum 16 mm. See Photo 3 below.

In connecting zones to adjacent non-refurbished areas the concrete blocks were milled within a width of 3 m to a thickness varying from 0 to 50 mm to obtain good level connection of the top asphalt.

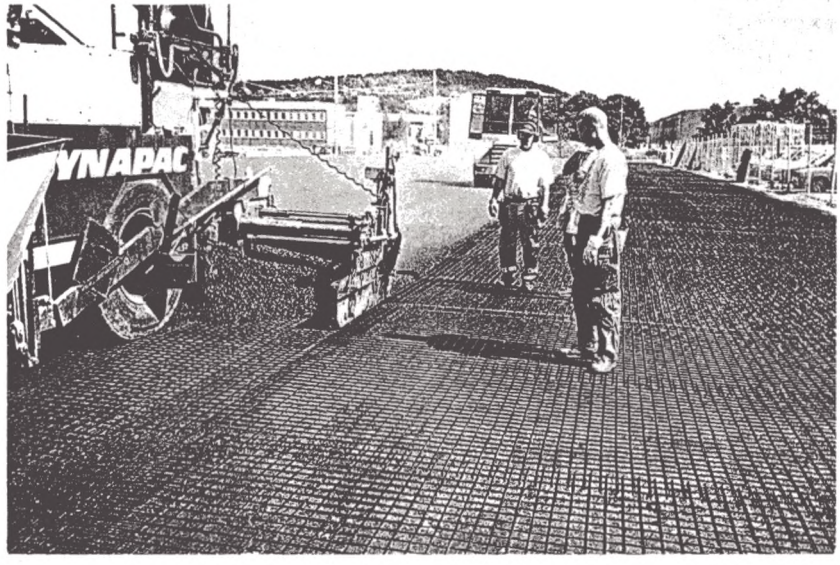


Photo 3. Laying asphalt on top of the CBP

Before the execution of the works a theoretical analysis was undertaken of the bearing capacity of the planned design. A comparison was made with the total refurbishment design (first step) and the recycling design (second step). In order to obtain a relevant bearing capacity the reinforced asphalt layer should be in the range of 25 cm. The cost for this thickness of asphalt would be too high to make it feasible.

However by reducing the thickness of the asphalt paving and placing the steel mesh in the bottom asphalt layer it will be possible in the future to undertake repairs only by relatively limited works. The refurbishment will then be done by a top milling of the top layer and laying a new asphalt layer.

In order to avoid severe settlements in front of the container stacks at the location of the front wheels of the braking FLT the subbase is reinforced. A layer of a 20 cm thickness of lean concrete with a cement content of 125 kgs/m^3 is included in the subbase.

6.2 Container stacking areas refurbished with CBP

As stated above we decided to have CBP in the stacking areas proper to withstand the corner load of the stacked containers. The reason being our experiences of severe intrusions in the asphalt surface from loaded container corners in old parts of the port.

Within these areas the old concrete blocks as well as the bed sand and 20 cm of the original bearing course of gravel was removed.

A layer of lean concrete of 20 cm thickness with a cement quantity of 125 kg/m^3 was laid and compacted.

Holes with a diameter of 50 mm at a grid distance of 1,0 m were drilled in the lean concrete to enable drainage water to penetrate through the paving.

On top of the lean concrete an ordinary CBP paving was built with a bed thickness of maximum 40 mm and concrete blocks of 10 cm thickness.

In line with **the Port of Helsingborg CBP polices** this CBP paving was done with rectangular blocks and they had an almost relevant curing age before they were placed in the paving preventing from being used at a too young age. This latter could be accepted as no trailer traffic would pass over the surface.

6.3 Costs

From economical point of view it was found that the costs for *the reinforced asphalt refurbishment* amounted to about 19.- USD/m^2. This should be compared to the costs for the "recycling" alternative of 54.- USD/m^2.

The recycling project was designed for the same quality criteria as the initial full refurbishment project. A 20 years expectancy of only limited maintenance input was planned.

For the reinforced asphalt refurbishment project it is forecasted that wheel tracks will develop due to the weaker design of the structure. It is estimated that partial milling and an additional asphalt top will cost in the range of 12 USD/m^2. Consequently this operation can be undertaken three times before the lower quality paving project becomes more expensive. This conclusion does however not take into consideration the net value aspect of future repavings.

The costs for the *concrete block paving* within the stacking areas have been calculated to 27 USD/m^2.

6.4 Experiences

The total refurbished terminal area of about 15.000 m^2 has been in operation for two full seasons including one very hot summer season. So far no problems have been identified as far as rutting is concerned.

From technical point of view it was found that it is extremely important to obtain a very even top surface by laying a levelling course of asphalt before the nets were placed on the concrete blocks. Remaining local settlements would cause a future unstable paving and new local settlements will developed quickly.

Special attention also had to paid to the connection between the different sheets of the reinforcement nets so that no multiple net thickness occurred. This showed to be particular important in points where four nets were connected. Experiences showed that this was very important as the paving would otherwise be cracked.

It has been found that it is extremely important to have a well designed connection in the subbase between the totally refurbished CBP areas and those areas where only limited works were undertaken. By experience it has been found that a slope of 2,5:1 has given the best result in order to avoid local settlements.

It has been found that the final asphalt cover on top of the reinforcement nets must be at lest 70 mm. Initially a thinner asphalt coverage was used. This gave cracks in the joints between the different courses of the asphalt paving.

7. CONCLUSIONS

A CBP repair method has been used in the Port of Helsingborg, Sweden, where reinforced asphalt has been lain on top of an existing CBP. After two years of normal port operations the paving is still in good condition. A substantial saving in repair costs has been obtained in comparison to a complete reconstruction project.

It has however been experienced that one has to be very careful when undertaking repair works by using reinforced asphalt.

Helsingborg, Sweden, February 10, 2000