Use of block paving in European ports

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Introduction

AS you will have read I am the Manager, Facilities Engineering, of the Europe Container Terminus (ECT) in Rotterdam (Figure 1), and in this position I am responsible for the design and maintenance of the architectural and civil structures at this container terminal in the world's largest port.

Since the first container shipment took place in the USA in 1955, this form of transport has spread all over the world, and today approximately one half of all general cargo is transported in containers, using a network of hundreds of container terminals.

During the last 10 to 15 years, at least a hundred container terminals have been built in Europe. Such terminals, as well as other European industrial plant expansions, are a combination of several technical disciplines including mechanical, electrical and civil engineering.

It is worth remembering that ⅔rds of the total investment in a container terminal relates to civil works, such as: the quay wall, the stacking yard, buildings, cfs, etc.

A quarter of this ⅔rds is required for terminal surfacing and, as I have already said, this applies not only to container terminals, but also to other industrial areas.

The ICHCA pamphlet written by Robert West states:

> "Paving is a complicated matter requiring a scientific knowledge of the properties of the ground, of the strength and other characteristics of the pavement itself and of the type, frequency and intensity of loading".

Or, as was said by Oostenbroek, in an article in *Cargo Systems* of April 1979, "Terminal surfacing brings the problems down to earth".

As I have pointed out, however, I prefer not to speak about container terminals only, as block paving affects every industrial area in the world. However, as I have been working in containerization from the start, it is inevitable that most of the work I mention deals with our container terminal, because that is where my experience lies.

European ports

Being civil engineers—constructing, building and maintaining terminals—we have to know what is going on in our terminal. For calculations we need to know wheel and axle loads, wheel configurations and frequencies (Figure 2). In a port we handle general cargo, raw bulk cargo, oil and containers.

For many civil engineering reasons—and mainly because they do not require concrete blocks—I shall leave out terminals handling raw bulk cargo and petrochemicals. I shall limit myself to general cargo and container terminals or, as is sometimes found at small ports, a combination of these.

Every general cargo stevedore also handles containers, and all general cargo ships carry containers on their hatch covers. As far as the loads in the yard are concerned, this implies that both types of terminal are the same.

Figure 1: Aerial view of the Europe Container Terminus, Rotterdam.

Figure 2: Some equipment is extremely large.

To handle this cargo, a variety of quipment is available. I am sure hat every company tries to buy quipment different from its neighbour's, and if possible to get it ar from home so as to have a eason for a nice trip. It is a pity that here is no container crane or straddle carrier factory in Barbados!

Every equipment manufacturer naintains that his products are better and cheaper than those of his competitors.

I am, of course, exaggerating, but think it gives you a better view of he equipment market, which in my pinion is more complicated than he civil contractor's market.

In most cases the mechanical ngineers do not take much account of the civil impact of a new piece of quipment, and I must admit that he reverse applies also.

For that reason, and to digress for moment, I want to make a plea for better integration of the various echniques in the interests of a echnical and financial optimum for he equipment and civil construcion.

It should not be possible to purchase equipment that is too heavy to perate and drive over a terminal. It s an immense waste of money and et it has actually happened.

To bring the problems down to arth I should like to illustrate the vide variety of equipment which we have in the ports:

Trailers	20 ft 40 ft special RO-RO trailer (mafi)
Fork lift trucks	light medium heavy
Trucks	normal heavy
Straddle carriers	2-high 3-high 4-high
Multi-trailer system	
Stacking cranes	rail mounted rubber mounted
Rail cranes	
Quay cranes	first generation last generation (costing 10 million guilders each)

ome of these are illustrated in igures 2 to 6.

I believe that, after this enumeraon, it will be obvious that, for the andling of containers, a variety of quipment is, and must be, vailable. And besides varieties in requencies, every piece of equipment has its own wheel loads, axle oads and wheel configurations. These factors, together with the subil at the location, form the basis

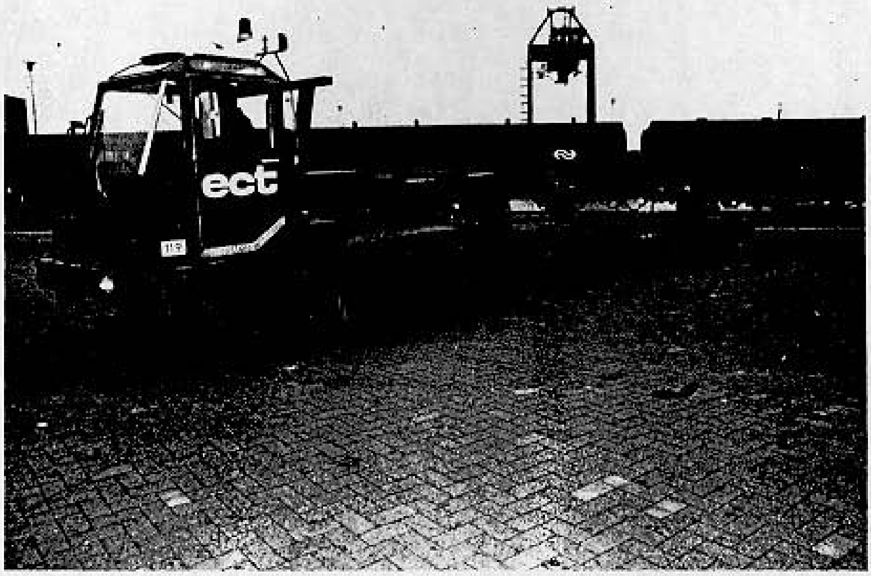


Figure 3: Special Ro-Ro trailer.

Figure 4: Heavy-duty fork lift truck.

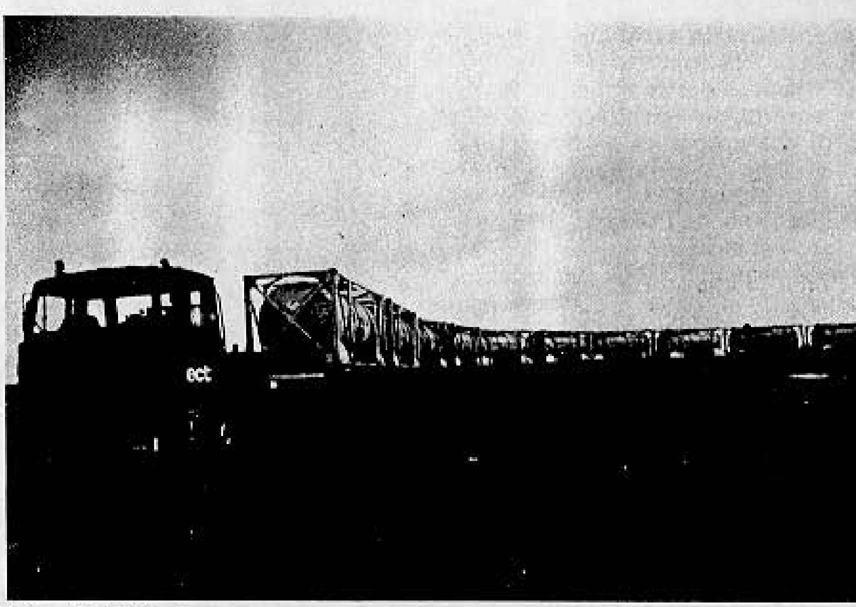
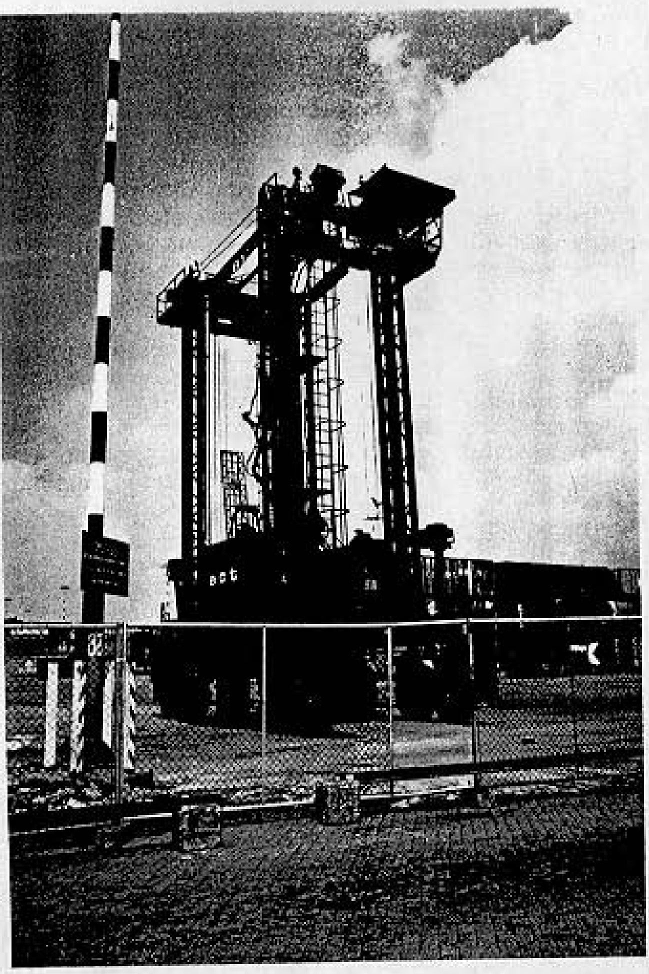
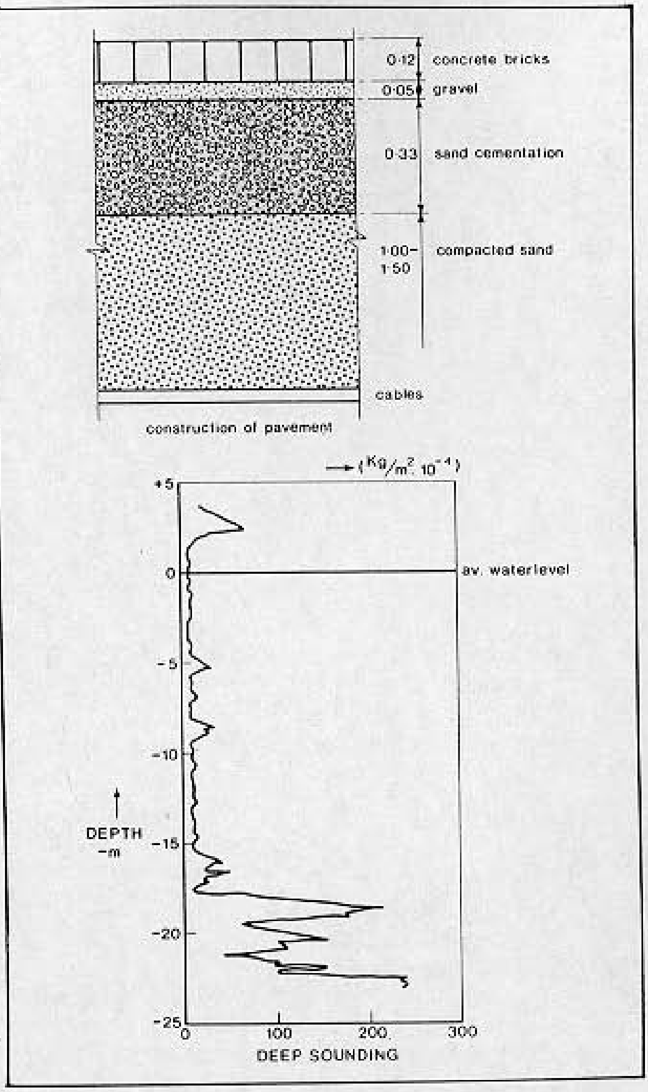


Figure 5: Multi-trailer system.





Above. Figure 6: A 4-high straddle carrier.

Right. Figure 7: Typical pavement construction, and example of deep sounding graph.

for determining the terminal surfacing.

I would now like to show you (Figure 8) an example of a simple load and wheel configuration on the surfacing; the chassis, 10 tons per axle (in Germany 12 tons per axle will probably be used in the near future). Straddle carriers 3- or 4-high impose loads of up to 15 tons per wheel on 8 wheels—this is a Dynamic load. A example of an extreme Static load is 4 or 5 containers stacked on each other, as in Figure 9, where a 30 to 40 ton load is being imposed on a 15 centimetre square of pavement by each of the 4 corner castings.

In order to enable civil engineers to deal with all these different loads, wheel configurations and frequencies as far as block paving is concerned, it is obviously necessary to make use of theoretical calculations and empirical methods in the dimensioning of the construction.

A very important factor in the construction of a terminal is settlement. Because of it, we in Holland come closer to our friends in the Antipodes every year!

Many, perhaps almost all, terminals in the world are situated on reclaimed land in alluvial areas, and everybody is therefore familiar with settlement. At our terminal in Rotterdam, for example, we had to face a settlement of 1 to 1½ m in the first 10 years (Figure 10).

This rapid settlement necessitated flexible pavement construction, and consequently a special sewer system had to be designed. The pavement

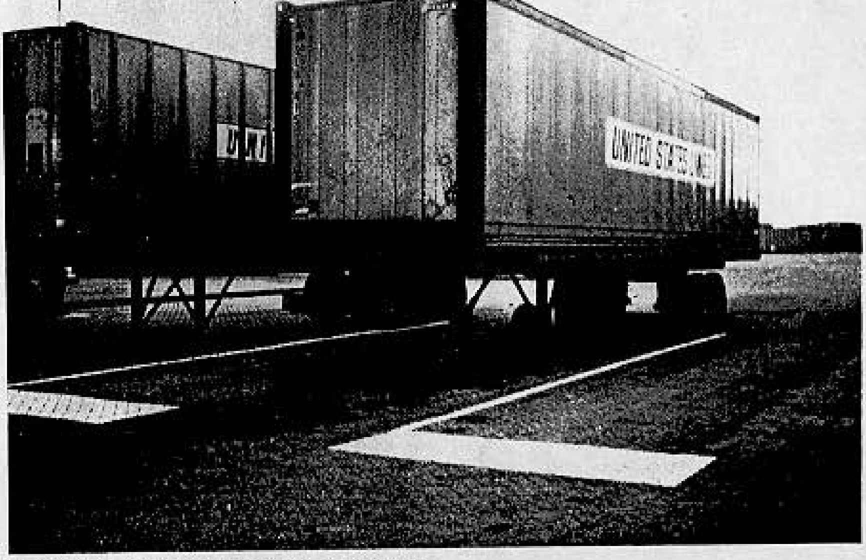


Figure 8: Simple load and wheel configuration.

also had to be easy to lift so as to interfere as little as possible with the operation. Fortunately, the settlement has now almost come to an end.

In addition to the theoretical and financial aspects, maintenance also plays a part in arriving at the best possible solution. In co-operation with the Ned. Heidemij., ECT has undertaken numerous investigations to determine the effect of different loads on different surface constructions, and their influence on the expected settlement and the existing subsoil. We found that the best construction for our terminal was:

33 cm of stabilized material (sand-cement)
5 cm of crushed rock or gravel
12 cm thick concrete blocks (10 × 20 cm).

In addition to block paving construction, other systems, such as concrete rafts (e.g. Stelcon, which is used in Southampton by the BTDB) and asphalt were investigated, but I do not feel that it is necessary to go into these in detail as our purpose here is to discuss concrete blocks.

The only thing I want to emphasise is that for Dutch—and more specifically Rotterdam—circumstances, rafts and asphalt are considered to be inferior to concrete block construction, from both the technical and financial points of view.

Anyone who is responsible for an industrial or container terminal would do well to avoid asphalt. It is unable to bear either static loads, or very heavy dynamic loads. There are also problems with hydraulic oils and petrochemical products, and it is very expensive, especially since the energy crisis. Moreover, asphalt must be used in conjunction with satisfactory stabilization.

Flexibility (for maintenance) and rigidity are important; flexibility because of the settlement to which I have already referred, and rigidity (and here we come to the use of the blocks) for various reasons including:

terminal trailers with no brakes (low investment),
straddle carrier tyres without profile,
oil spillage, and
multi-trailer system.

Other considerations are:

strength,
ease of maintenance,
low investment, and
low energy consumption.

A pavement design is an optimum combination of skill and experience, and even more it is an optimum in terms both of investment and of maintenance costs.

At ECT, we opted for a 12 cm thick concrete block. After many trials in 1966 and 1967, we found that, although a 10 cm concrete block was strong enough, the trouble was its tendency to overturn. The concrete blocks had not enough resistance to the loads resulting from the small turning radius (because of the type of equipment used and the lack of space on the terminal), plus the high axle loads. For that reason we decided on a 12 cm concrete block.

The following facts give an idea of the quantities of 12 cm concrete blocks used at the ECT terminal:

Paved area: 1·1 million m^2 (110 ha. or 275 acres)
6·6 million kg concrete = 6,600 tons.

We started in 1967 with 100,000 m^2 and after 13 years we can say that the decision which we made at that time was the right one. If ECT had to start again (and this may be the case in the near future) the same decision would be made.

A block paving construction requires:

a good stabilization layer to spread the load over the subsoil,
a good drainage system, depending, of course, on the climate location (in Western Europe we are all too familiar with the problem of rain),
concrete blocks, 12 cm thick.

Every decision must be based on co-operation between the civil and mechanical engineers, since my mechanical engineering colleague wants a construction that is suitable for his equipment.

Some facts

I should now like to present a comparison based upon Dutch prices

Figure 9: Containers stacked 4 or 5 high.

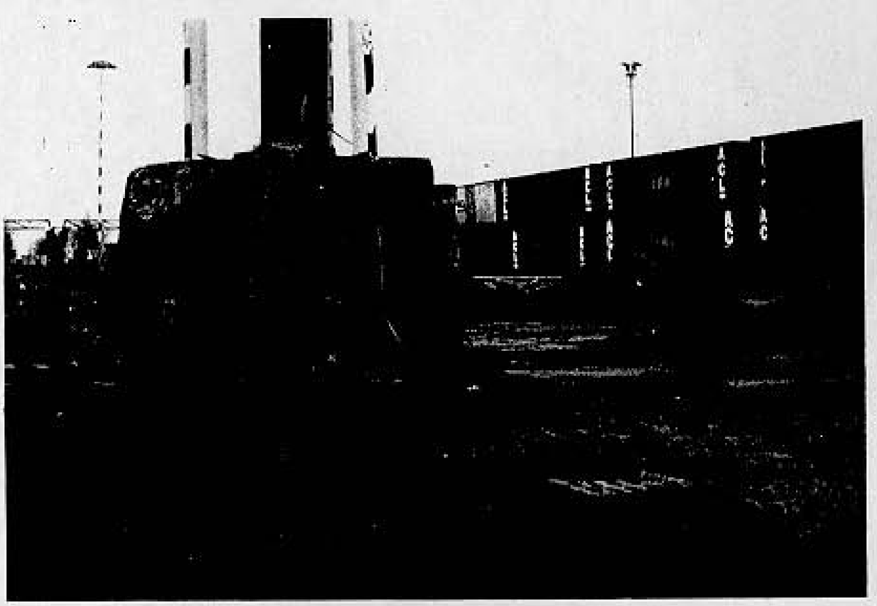


Figure 10: Restoration work following settlement.

and experience (Table 1). All construction—concrete blocks, asphalt and Stelcon or general concrete slabs—needs a certain stabilization layer. With no stabilization whatsoever, Stelcon or general concrete slabs give a lot of problems right away.

We need manpower, which in theory is available with the present high unemployment, but there are not many workers who want to do a job like this, because every block weighs 6 kilogrammes. Can you imagine one man laying 165 m^2 of concrete block paving per day? That is 6,600 blocks with a weight of 40 metric tons. Cost in Dutch guilders: about *fl*7 per m^2. This figure includes shovels, machines, etc. but excludes materials.

We have tried and are still trying to automate the laying operation, but up to now we have not had much success.

Table 1: *Prices per m^2 in Dutch guilders (fl) for different pavements (1 Jan. 1980).*

	Concrete blocks		*Asphalt*		*Stelcon rafts*	
New construction		*fl*		*fl*		*fl*
fieldwork		2		2		
drainage		6		6		
digging		2		2		25
stabilization	30 cm	15	30 cm	15		
blocks including crushed rock	12 cm	30	14 cm	30	12 cm	55
Total		*fl*55		*f*55		*f*80
Maintenance	1 × 10 years incl. materials (fl16)		1 × 5 years and repair approx. 4 cm		1 × 5 years 50% broken	
5-year cost		*fl*8		*fl*25		*fl*25

Table 2: *Comparisons based on Dutch circumstances*

	Blocks	*Asphalt*	*Stelcon*
Investment* per m^2	*fl*55	*fl*55	*fl*80
Resistance to static loads	good	bad	good
Resistance to dynamic loads	good	bad for heavy loads	good
Oil	good	bad	good
Rigidity	good	bad	bad
Flexibility	best	good	better
Maintenance	low	3x	3x

*From Table 1.

Conclusions

Mr Robert West, of Robert West Page and Partners, said in his ICHCA pamphlet that concrete blocks appear to be successful for lightly loaded roads and pavements, but remain a little controversial for heavily loaded roads.

On the basis of my 15 years' experience, however, I would say that concrete block pavement is the best construction you can buy for a terminal. It has already been used for 13 years to our satisfaction in Rotterdam and, if I may mention this, we handle 850,000 containers per year (which is roughly 1½ million TEUs per year) and in the field of containerization we are the largest in the world.

On average, a container vessel arrives at our terminal every two hours, day and night, 365 days a year. Every day we handle about 2,500 road vehicles.

The scope of this paper does not, of course, permit a review of all the practical developments and experience in the use of block paving, but I hope it will give you a working insight into the use of block paving in our terminal at Rotterdam.