CONCRETE BLOCK PAVEMENTS IN BELGIUM

- NEW DEVELOPMENTS
- HARBOUR AREA OF ZEEBRUGGE

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UMMARY

he use of concrete paving blocks is still increasing for surfacing residential oads and industrial applications; this is due to their technical, economic and ttractive properties.
he first part of the report deals with the new developments in concrete paving locks, especially concerning the many different new forms, which are shaped to ;ive a particular decorative effect.
.n a lot of Belgian towns the special,often square, concrete paving blocks have ;een used to replace old cobblestone paving or asphalt, for instance to make shopping streets and pedestrian precincts such as in Liège.
Further on,design and construction aspects are reviewed, namely the thickness of the blocks, the joints, the bedding layer and the base, which is nostly cement-bounded for heavy loads.
The second part of this report deals with the experiences with 80 000 m^2 concrete paving blocks, 12 cm thick, placed on cement bonded subbases in the inner harbour of Zeebrugge on areas which consist of 2.5 to 3 m deposit of dredging sand.
At Zeebrugge a new type of sandbed was placed, i.e. a mixture of 0/2 and 0/4 crushed limestone, granular slag and lime. The advantage of this mix is that it stays workable for several days and becomes as stable as sand-cement in the long term.
Another innovation in the inner harbour of Zeebrugge are the L-shaped paving blocks, placed along the rails. These elements give higher stability than rectangular blocks. Also the use of a lean concrete base equivalent in thickness to the sleepers provides a successful substitution for ballast under the blocks between tracks to avoid deformation by post-compaction under the effect of heavy harbour traffic.

1. NEW DEVELOPMENTS

1.1 Introduction

In Belgium a great deal of the road network, mainly outside the urban centres, has a cement concrete pavement. In urban districts too they begin to prefer cement concrete.
Instead of monolithic pavements more and more small concrete elements are chosen. Not only for the construction or the renovation of streets and places, but also for the pavement of industrial areas and container terminals concrete paving blocks are applicated.
This growing interest for small concrete paving products, which now take the place of asphalt and paving stones in renovation works in city- and village centres, is for a great deal attributable to the increasing care for the living environment.
With concrete paving blocks it is possible to create pleasant looking and safe circulation areas. Both aesthetic and functional expression possibilities are existing, considering their form, colour, surface texture and laying patterns.

Since 1983 one uses mainly a great deal of concrete paving blocks for the pavement of industrial- and port grounds, for example in the ports of Antwerp (1) and Zeebrugge, where about 500 000 m^2 concrete paving blocks were laid on container terminals because they combine on an economical manner the technica advantages of flexible pavements with these of rigid pavements.
The increasing request for small concre te paving products, of which utilizati fields are even extending, has the result that many new - sometimes abroad but also in Belgium developed - types of concrete paving blocks are marketed These new tendencies in the field of paving materials and the recent experiences in relation with the realizati of pavements with different block type are dealt with in this paper.

1.2 Types of paving blocks

Concerning the form one distinguish now 3 types :
- rectangular paving blocks type A
- interlocking paving blocks type B

- special paving blocks

1.2.1 Rectangular paving blocks type A
The rectangular paving blocks, in normal or coloured concrete, which are defined in the standard NBN B 21-311 as type A are still most applied.
We drawn your attention to the fact that because of the "contignous" laying of the blocks, the formerly standardized dimensions had to be adapted. These were registered in addendum 1 of 1983 to NBN B 21-311 (1973) (see table 1)(2)

Table 1 : Nominal dimensions paving blocks (mm)

Length	Width	Height
220	73	80
220	110	80
220	110	100
220	110	120
220	130	130

The small rectangular paving blocks 220 x 73 x 80, most produced in red or brown colour, as clay bricks, and equipped with a little chamfered edge are an appreciated material for renovation works in villages and town districts (Photo 1).
Since 1983 the form 220 x 110 x 120 was introduced in Belgium too for the need of port areas where they are laid normally in herring-bone pattern.



Photo 1 : Renovation housing estate street in Hasselt with normal and small blocks

1.2.2 Interlocking paving blocks
In standard NBN B 21-311 these bl
are divided into two groups :
- blocks with simple interlocking
- blocks with interlocking and su

The interlocking type of which a
variety exists, is mainly applied
a large extent.
A form that is becoming known lat
to its optical effect, is the one
more square looking red block wit
interlocking ("Forum" 160 x 160 x
The in Belgium developed type "Vi
240 x 120 x 80 with strong interl
is applied as much in build estat
well as for industrial grounds (P



Photo 2 : Application "Viablok" in Centre Lauwe

1.2.3 Special concrete paving blo
Under this heading come concrete
blocks which owing to their shape
belong to either type A referred
ve, or to type B.
Generally speaking, they are block
which are shaped to give a partic
decorative effect.
Since the outward aspect of roads
public squares at present is rece
more attention, there is a growin
rest in special concrete paving b
Several manufacturers have theref
moved in line with these new requi
ments for paving materials and al
their ordinary range of concrete



Photo 3 : Renovation centre Liège
Combination of granite setts and
concrete setts "Blanc de Bierges"

blocks they are now offering a number of special effect blocks. A brief review is given below of the most successful types which help make our living environment more attractive and safer.

Square Concrete Paving Blocks

Perhaps the best known typically-Belgian special concrete paving blocks are the "Blanc de Bierges". These come in various dimensions modulates between them. The most successful format is 140 x 140 x 80. These blocks have a bright and warm colour and combine the aesthetic qualities of natural stone with the shape-retaining properties of concrete, creating a good-looking even and comfortable walking surface.
The company producing "Blanc de Bierges" has already received a number of awards. In 1985 it was once again honoured with the Bronze Distinction at Paris (SAD Industrial Prize 1985).
In many Belgian towns these blocks have been used to replace old cobblestone paving or asphalt, for instance to make shopping streets and pedestrian precincts such as in Liège (Photo 3 and Fig. 1).

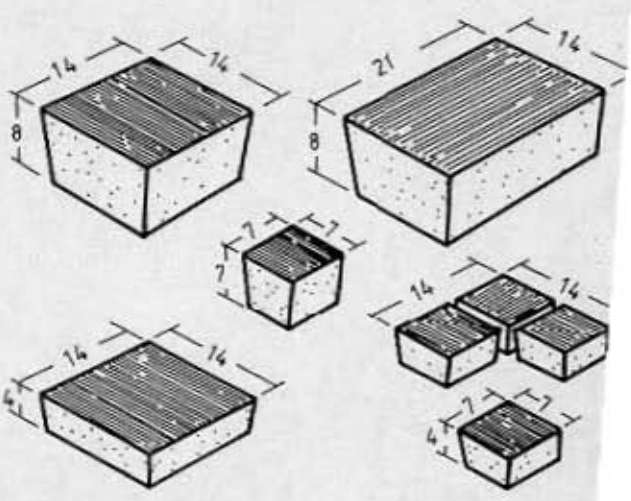


Fig. 1 : Modular types of concrete s
"Blanc de Bierges"

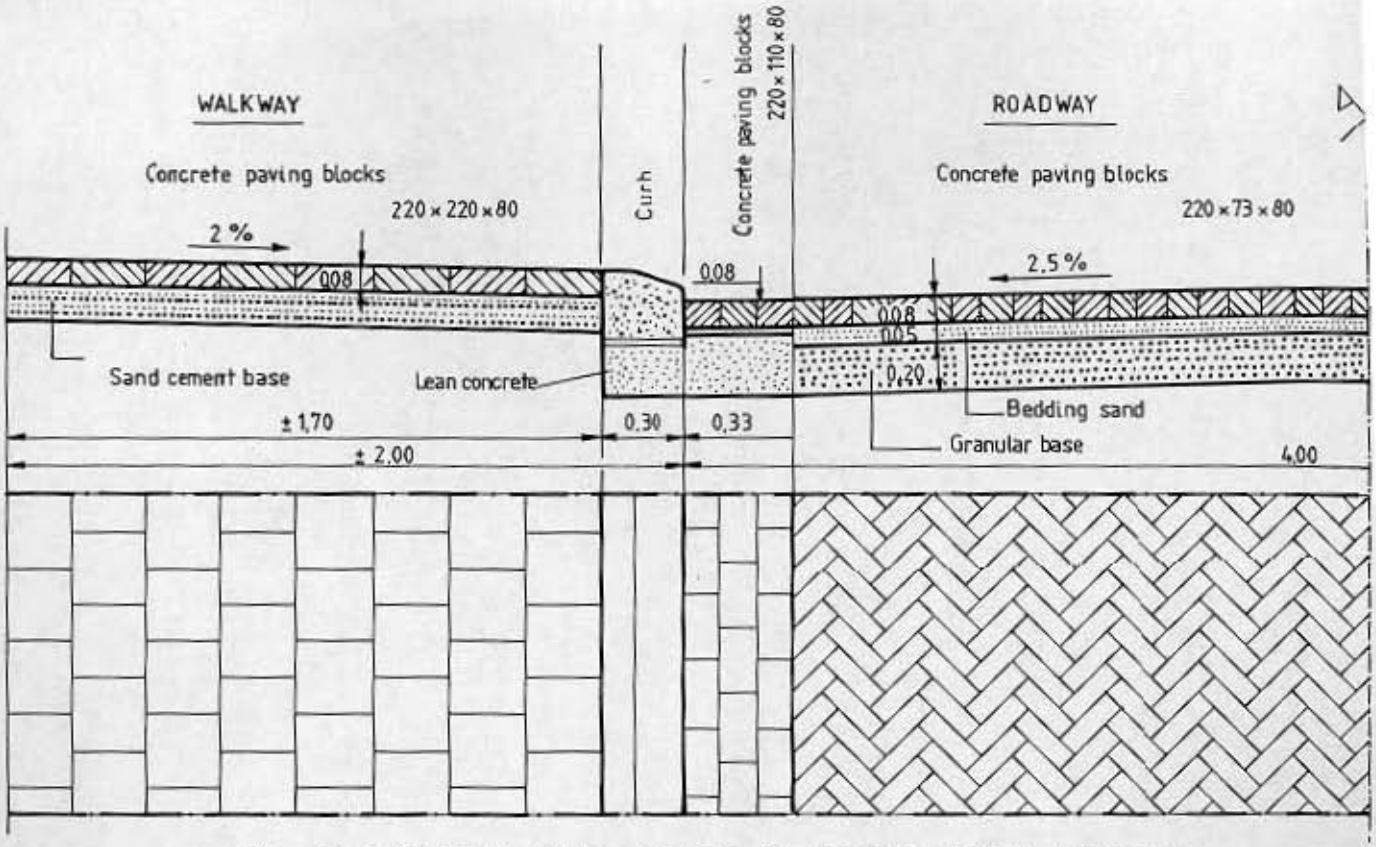


Fig. 2 : Typical cross section St Lazarusstraat Antwerpen

In the private sector too these products are highly favoured. It should be noted that, with a view to easy construction, concrete paving blocks of the type "Blanc de Bierges" are produced with straight sides as well as bevelled sides so that they can be laid just like ordinary paving blocks.
A number of other manufacturers have brought square concrete paving blocks in attractive shades onto the market, e.g. the Blanc Romain (140 x 140 x 80), Blanc Yvoir (140 x 140 x 80), Urba Design (140 x 140 x 80) and (140 x 140 x 120).
Another type coming into vogue is the format 220 x 220 x 80 (Fig. 2). This concrete paving block has the appearance of a small concrete flag, usually called the double block, and is mainly used in the Antwerp area for foot- and cycle paths where it is difficult to exclude stray road traffic. This paving block has also been successfully used in the town of Antwerp along tramlines (4).
One manufacturer who primarily produces concrete slabs, makes half-slabs of 300 x 150 with a false joint in the middle, giving the appearance of 2 blocks (a twin slab) measuring 140 x 140. These products are mainly intended for pedestrian zones and are usually made in rustic colours.

Combination Blocks
The different combination blocks are very much in demand. Usually they are relatively small and modular in shape so that they lend themselves to making designs, such as arcs and circles (Photo 4) (4).



Photo 4 : Designs with "Classico", Hasselt

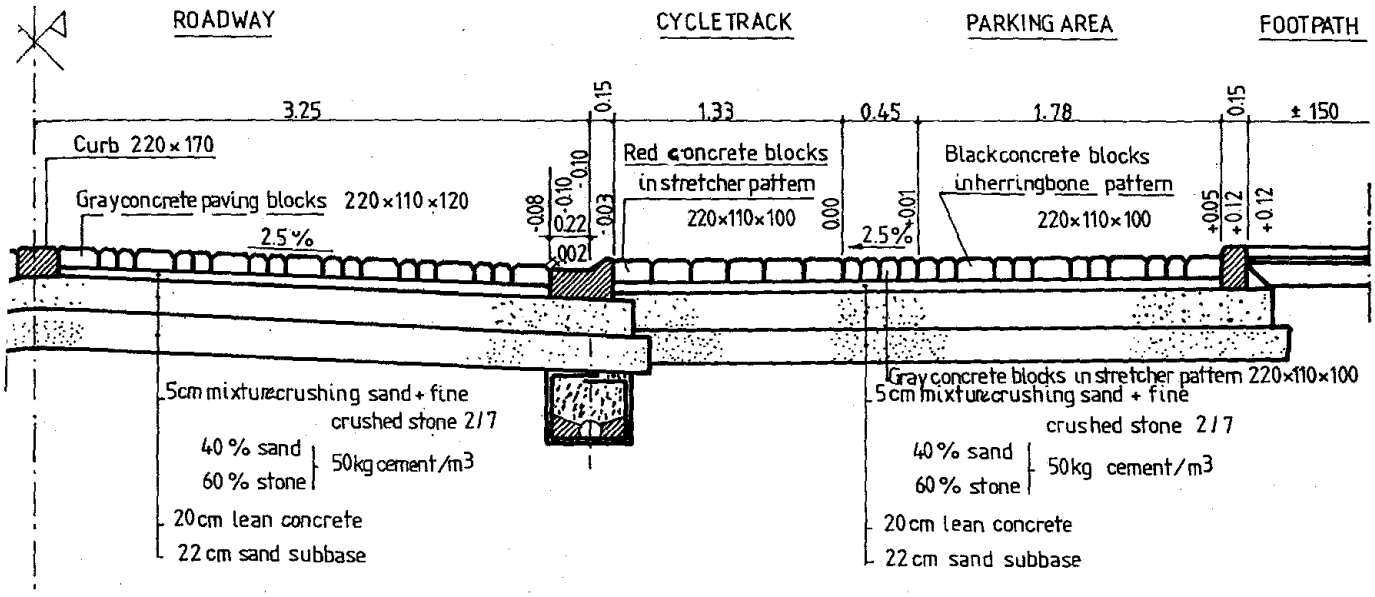


Fig. 3 : Cross section pilot project renovation N2 Louvain-Diest urban area Kessel-Lo (realisation M.O.W. Vlaams Brabant)

n recent times several kinds of concre- e paving blocks have been developed for illage and town renovation work as well s for private applications which have he appearance of old cobblestones or osaics but nonetheless have a relative- y even walking surface. Some types ven allow fan bonds to be laid, crea- ing a great similarity to mosaic stones hich are much more expensive and diffi- cult to walk on. Furthermore, efforts are also being made at present to give cobblestone-look blocks a regular shape on their underside so that they can be laid closely, while maintaining their irregular upper surface to create a va- ried jointing pattern.

1.3 Standards and Benor mark

The Standard NBN B21-311 + Addendum 1 (1983) sets out the characteristics concerning shape and durability, and in- dicates the requirements which they must meet (2).
Only blocks of type A (rectangular) and type B (interlocking) are subject to shape requirements, while in the case of special blocks these must be indicated by the manufacturer.
In the light of the current developments with regard to concrete paving blocks, work is now being carried out on a re- view of the standard so that, among other things, for the laying of blocks smaller deviations in measurements are established in advance, namely for the length and breadth : +/- 2 mm, and for the thickness : +/- 3 mm.
As far as the physical and mechanical characteristics are concerned, such as compressive strength (> 60 N/mm^2) and waterabsorption (< 5 %), no adjustments worth mentioning are necessary.

On the other hand, steps do need to be taken to measure the resistance to dei- cing salts by conducting simple tests. This is particularly useful in the ap- plication of special blocks and those with coloured wear layers on public pa- vements.
Since January 1986 Benor authorisations have been issued in Belgium for standard concrete products for roadbuilding, in- cluding concrete paving blocks (5). The products inspected in the factory there- fore no longer need to be examined at the site or in advance. In October 1987 there were about 15 manufacturers produ- cing concrete paving blocks with the Benor mark.

1.4 Some design and construction aspects (6)

1.4.1 The pavement

Thickness of the Blocks

The tickness of the blocks depends to a large extent on the field of applicatio as well as the type of block.
For ordinary paving in built-up areas, in the case of rectangular blocks, usually laid in an herringbone pattern, these mostly have thicknesses of 8 of 10 cm. Greater thicknesses are only used for areas carrying a heavy traffic load, such as at container terminals where 12 cm is common.
When square or rectangular blocks are used on roadways and in urban conurba- tions sometimes concrete setts 12 cm thick are chosen and laid closely to- gether (Fig. 3).

Joints and Joint Fillings

It is nowadays the general practice i Belgium for both rectangular blocks an

interlocking blocks - usually laid by hand or mechaniccaly - to be laid closely together. The narrow joints between the interlocking blocks are almost filled with fine - if possible dry - 0/1 sand.
When for particular pavements relatively wide joints (3 - 5 mm) are wanted for aesthetic reasons, the joints are then filled in with course crushing sand.
Only really wide joints (8 - 10 mm) are filled with cementmortar.

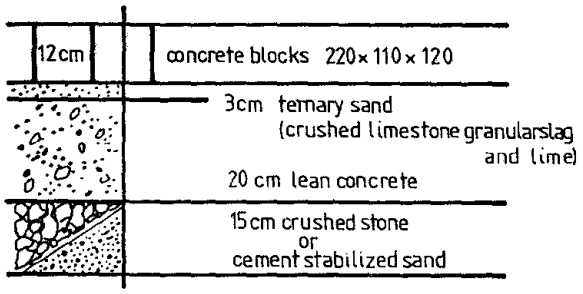
1.4.2 Pavement bedding layer
The materials usually employed for the bedding, which must remain stable in all weather conditions and is 3 - 5 cm thick in the compacted state, are medium course or course sand, sand cement and, in recent times, also a mixture of crushing sand and 2/7 chippings, used e.g. for harbour areas, bus stops and roads.
A relatively new development is the application of a mixture consisting of limestone - crushing sand 0/2, limestone 2/4, slag sand and 2 % lime (used for example at the Zeebrugge harbour area (see part 2).
Before the blocks are laid the pavement beddings of sand cement are often compacted first of all and also screeded and then the top few centimeters are raked so that the blocks can be laid.
By proceeding in this manner when the concrete paving blocks - particularly those provided with an abrasion layer - are vibrated they are less prone to damage than if they have been vibrated on a 4 - 7 cm thick uncompacted bedding.
In general, however, thick bedding layers are not to be recommended, although in some cases, such as when renovating old pavements, the bedding layer often acts as a kind of profiling layer for the (retained) base and local relatively great thicknesses are hard to avoid. In such cases the technique referred to above seems to be a good solution.
When some types of special concrete paving blocks such as "Blanc de Bierges" are being laid, and if broad joints (8 - 10 mm) are used, the blocks are in many cases placed on a 2 - 3 cm thick bed of mortar or sometimes on sand cement. Such bedding layers are particularly called for in the case of relatively thin decorative paving blocks used in combination with concrete flags or slabs.

1.4.3 Base
Thanks to the good frost-resistant bases available (7)(8) ranging from crushed stone to lean concrete, problems seldom arise concerning the evenness of the paving.
Crushed stone, normally 20 to 25 cm thick, is mainly used when underlying pipes/conduits must remain easily accessible, and in cases where traffic is light.
Cement-bound bases, such as lean concrete, sand-cement and cement-treated crushed stone, in most cases from 15 20 cm thick, is used particularly on surfaces carrying a heavy load. However their technical qualities and ease of workability mean that they are often used for surfaces with light traffic loads as well, such as for foot- and cycle paths.
As regards what is sometimes called the "hammer + anvil" effect when concrete paving blocks are laid on a cement-bound base, there is absolutely nothing to worry about so long as it is ensured that the joints remain well filled, blocks are at least 8 cm and if possible 10 cm thick, and that there is a proper water run-off and suitable drainage.

2. APPLICATION OF CONCRETE PAVING BLOCKS IN THE HARBOUR AREA OF ZEEBRUGGE

2.1 Introduction

Zeebrugge harbour has been making great advances since 1970. For it was in that year that work was started on constructing a new inner harbour on a 1200 ha site. This harbour area was linked to the sea by a large new sea lock, designed for shipping of 125 000 tonnes.
The building of a first intermediate dock with a quay wall totalling 2 km in length ensured that the advantageously-situated land could be made available for harbour operation, particularly freight handling.
However, this formerly low-laying agricultural land first needed to be raised in level by ≃ 3 m. This was carried out by means of hydraulically pumping up the spoil dredged from the dock access channels and from the dock itself. The composition of the spoil was a mixture of sand, clay, loam and peat.
After the land level had been raised work commenced in 1983 on laying the pavement. In view of the nature of the land-raising work and the composition of the soil, it was decided to opt for a flexible pavement, namely concrete paving blocks. An additional advantage of concrete paving blocks is that when new harbour areas are being installed it must always be possible to lay extra industrial pipes and cables without incurring excessive costs and problems. The structure of the pavement is given in fig. 4).
In this section the importance of the base is clearly shown as well as of the choice of type and thickness of the concrete paving blocks themselves.
The structure in more detail is set out below :



4 : Cross section concrete block pavement inner harbour Zeebrugge

Sub-Base

the raising of the land level a de- d CBR value of ⩾ 7 was laid down as quirement. With a view to meeting requirement a grid plan was drawn or conducting penetration tests. checking was necessary owing to method used for raising the land le- (hydraulic) and the nature of the . pumped over the land. The large ɔer of pumping areas with a small ɜace area each time gave a zone of il with a high silt content. The sence of pumping dikes at the edge the land and of a clay-rich subsoil e it virtually impossible to drain ground. The solution was twofold : connect it up to a drainage system the original ground level (≃ 3 m p) and to replace the large quantity silt with good quality sand. Once s work had been completed the level- g of the land could commence. most advantageous solution was the situ stabilisation of the land. The cifications were that class 30 stfurnace cement would be employed. t specimens at the site produced in ordance with the Standard Proctor t had to have an average compressive ength of 2 N/mm^2 after 7 days (8). r a large proportion of the surface tests gave satisfactory results. the remaining part (again depending the pumping areas) stabilisation was possible. Quality controls of the soil in certain parts indicated a centage of organic substances ranging m 1.5 % to 4.85 %. With such results was decided to replace stabilisation these zones by a crushed stone base ch complied with the requirements of gian Type Specifications 150 (7).

Base

base consists of 20 cm of lean con- te. The thickness was determined by high load strength which the base t possess. For harbour areas do have cope with a heavy traffic load (1).(6). type of subsoil coupled with the re- rement that land settlement must be e to take place without causing any l problems, swayed the choice in favour of lean concrete, while at the same time limiting the maximum compressive strength. The specifications required that the compressive strength of cylinder test specimens average 10 N/mm^2 after 90 days, and individually at least 7.5 N/mm^2.

With the aim of securing a water outflow between the surface underlying the concrete paving blocks and the lean concrete, drainage holes were made in the lean concrete at intervals of 15 m^2. These were filled up with gravel and are sufficiently large (≃ 30 cm diameter) to ensure a permanent water outflow.

2.4 Bedding layer

There were 2 possibilities here : a mixture of 40 % crushing sand + 60 % crushed stone 2/7 or ternary sand. The ternary sand was used in the construction. This mixture, obtained from the limestone quarries, was prepared at a mixing plant and contained 0/2 limestone-crushed stone, 2/4 crushed limestone, granular slag, lime (2 %) and water.

This mixture was spread in a slightly over-thick layer and then compacted into a single layer with a vibrating roller. Next it was vibrated with a heavy roller with smooth roller cylinders. It may be necessary to protect it with an after-treatment product against drying out. The hardening process is slow and after some months it acquires better mechanical properties than ordinary crushed stone bases. The documentation on this subject (9) indicates that after 28 days the compressive strength on Proctor Test Specimens should be 1 to 2 N/mm^2. Practical tests on-site gave results of an average 1.9 to 2 N/mm^2 after 7 days. The humidity content of this mixture amounted to 8 % (see gradings Table 2).

Table 2 : Gradings of bedding ternary sand

Sieve sizes (mm)	Recommanded percentage finer than (by mass)	Average results at Zeebrugge
7	100	99,9
4	82 - 100	97,9
2	44 - 63	65,7
1	25 - 42	39
0,5	14 - 28	22,8
0,25	8 - 20	14,6
0,125	5 - 13	10,9
0,080(⋆)	4 - 11	9,9

(⋆) The finer parts can only come from the crushing production

The mixture has the following advantages :
- immediate very good load-bearing capacity
- compacting very rapid
- mixture remains easily-workable for a long period (setting and hardening extremely slow)
- thin layer thicknesses are possible
- no risk of the mixture separating out
- little risk of cracks developing
- less vulnerable to torrential rain than other mixtures
- subsequent compaction is possible.

2.5 Concrete Paving Blocks

By comparison with other fields of application, harbour areas have several typical problems, including the following :
- extra heavy loads
- subsidence due to land level being raised
- differential settling between quay walls and land
- presence of crane and train rails
- presence of many industrial pipes/ conduits and need for additional installation or modifications
- drainage of large surfaces.

The large loads call for concrete paving blocks with maximum dimensions, namely 220 x 110 x 120 mm. These blocks were, furthermore, laid in herringbone bond with a view to improving general stability. The laying was done entirely mechanically. The blocks meet the usual requirements. The table below sets out the requirements and the values obtained :

		requirements	test results
compressive strenght	average	60 N/mm^2	88 N/mm^2
abrasion	"	<3.5 mm	0.65 mm
water-absorption	"	< 5 %	4.2 %

Even with the quality requirements of the concrete paving blocks being met, there were other problems which were difficult to resolve. The presence of the many railtracks was the prime cause of the problems here. By contrast with the land itself, the foundation base in the area between the rails was not sufficiently compacted and the composition itself (crushed stone without filling materials) must be totally rejected. The application of this old system led to the following end result (Photo 5). The reason why the railway track calls for this method of construction is the need to allow the rails to be taken up in the event of subsidence. In view of the fact that the harbour operation cannot tolerate such a construction the foundation base technique using lean concrete was extended to between the rails. The result is totally different (Photo 6).

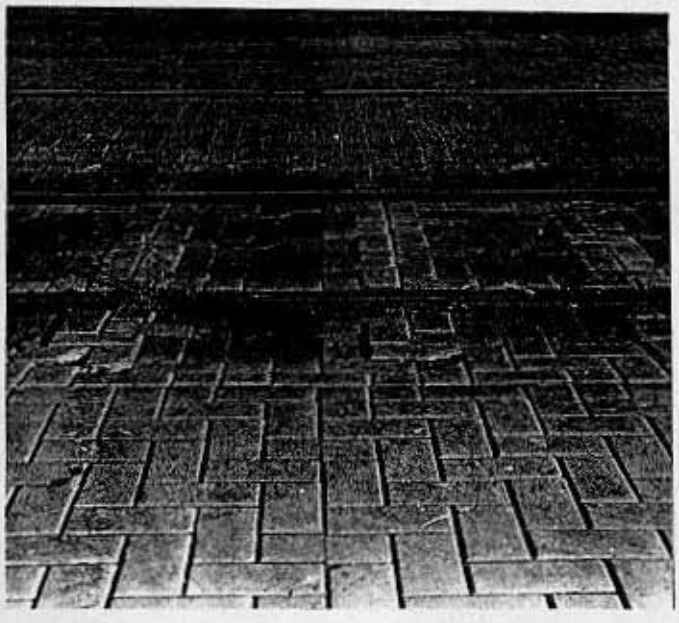


Photo 5 : Deformations with crushed stone base between the rails

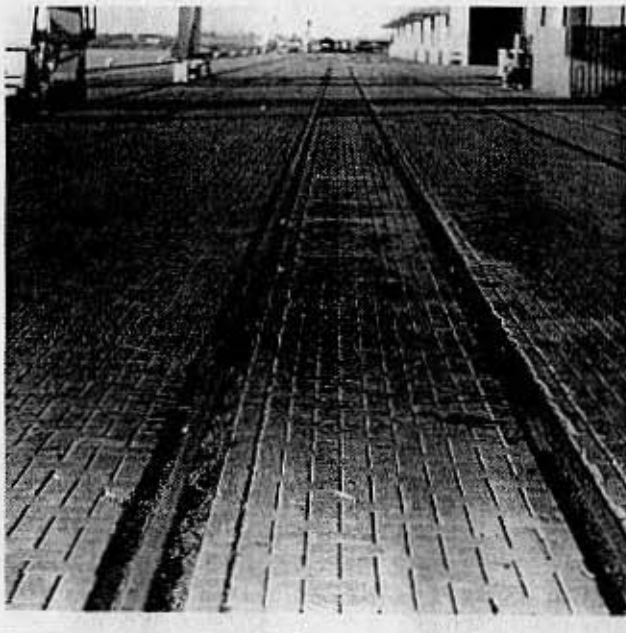
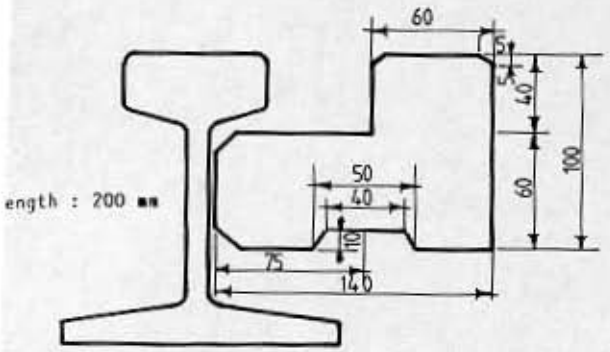


Photo 6 : No deformations with lean concrete base equivalent in thickness to the sleepers

additional problem with the rails is
: area between the rail section and
: concrete paving blocks. For the
ain wheels must be able to move freely
:hin a certain height and depth in
is narrow area at all times. Initial-
an L-shaped section iron was used for
is purpose. After some study the
itch was made over to a new special
ncrete paving block "Lithobeton"
ig. 5).



ig. 5 : L-shaped paving blocks along tracks

he avantages are :
concrete paving blocks cannot tip up so that the joint remains open
the dimensions are such that the normal blocks referred to above are laid mechanically in between (cost price)
no joint filling is necessary between the track and L section (maintenance).

he water outflow from the land is chieved by means of transverse water ischarge channels in the concrete pa- ing blocks. These direct the water nto discharge gulleys in concrete (e- ery 17 m) which are connected to the ewers (Photo 7).

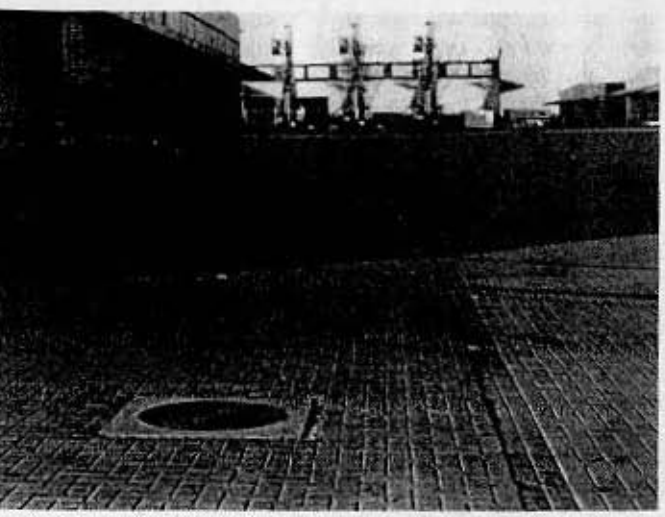


Photo 7 : View of a manhole and discharge channel with gulleys

On the quay wall itself the drainage channels were installed in concrete. These channels are prefabricated and have dimensions of 45 x 40 x 100 cm. The reinforcement consists of steel webbing. They are resistant to a pressure of ≈ 40 tonnes on a plate of 15 cm diameter. The upper surface has 8 apertures. The base has to be soundly constructed in accordance with the quay land itself so that differential subsidence is reduced to a minimum.
The upper surface installed covers an area of ≈ 80.000 m^2 and was constructed in 1984-85.

Customer : Ministry of Public Works
Coastal Service - Ostend

Contractor : N.V. Aswebo - Drongen

References

1. HENDRIKX L.
Concrete Pavements for container loading areas alongside Delwaide Dock, Antwerp K.VIV
8th International Harbour Congress Antwerp, 1983
2. I.B.N.
NBN B21-311(1973) + Addendum 1 (1983)
Pavés en béton - Betonstraatstenen
Bruxelles - Brussel
3. FEDERATION DE L'INDUSTRIE DU BETON
Catalogue Permanent Industrie du Béton 10/86 II F Pavès en béton
Revue BETON n° 87 FeBe Bruxelles 1987
4. VANDEPUTTE J., HENDRIKX L.
Utilisation des pavés en béton. Réalisations en Belgique.
CEMBUREAU - Association Européenne du Ciment
5e Symposium International des Routes en béton. Thème B.
Aix-la-Chapelle, 1986
5. PROBETON
Note d'information 1 (2ème édition)
La marque Benor pour les produits en béton de voirie.
Bruxelles 1987
6. HENDRIKX L.
Betonstraatstenen en Betontegels
V.C.N. Br/48/n Brussel, 1982
Pavages et dallages en béton
F.I.C. Br/48/f Bruxelles, 1982
7. Type-Bestek 150
Ministerie van Openbare Werken
Wegenfonds Brussel 1978
8. Type-Bestek 200
Ministerie van de Vlaamse Gemeenscha
Algemene Technische Diensten
M.O.W. Brussel 1983
9. STEYAERT W.
Toepassing van "Ternair zand" als straatlaag (legzand) voor betonstraatstenen
Ciments d'Obours S.A. Obourg 1983