THE MINIMUM THICKNESS OF CONCRETE BLOCKS ON A BASE COURSE IN CITY STREETS

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SUMMARY

In the Rotterdam area usually small elements are applied for paving roads and streets. Rotterdam Public Works is in charge of the design, the construction and the maintenance of the public pavements. Not only the renewing of the method of construction (mechanical paving) and the application of recycling materials are in focus, but also the optimization of the technical design. In order to diminish the paviour's hard work a solution can be reducing the thickness of the concrete paving blocks; because for the time being a substantial part of the total amount of paving work still has to be done by hand. This paper deals with a field test concerning this item.
A full scale experiment has been set up to examine the influence of the thickness of the blocks as a parameter for the total pavement structure, in order to find a minimum value for the thickness of concrete blocks when a base course is applied. In each test area a different block thickness has been used, varying from 60 mm to 90 mm.
This experiment has not ended yet. But some preliminary conclusions can be drawn.
The 80 mm and 90 mm thick blocks behave very well. The 60 mm blocks show substantial cracking. Some cracking occurs in the 70 mm blocks section. The final exact value for the minimum block thickness for these Rotterdam circumstances depends on other parameters, too. It is expected to be between 70 mm and 90 mm.

1. INTRODUCTION

World's largest port is the Port of Rotterdam with a transfer of about 230 tons yearly. The goods shipped in are transferred to inland vessels, trains, pipelines and trucks, and vice versa. Especially due to the growing container transport the transport by truck is still increasing. Therefore the Rotterdam road network is extensive and the connections to the hinterland (Benelux, Germany) are good.

Rotterdam is situated in the western part of The Netherlands. In this low-lying land the subsoil is relatively weak and the buildings are usually founded on piles. Streets, roads and area's are subjected to normally uneven settlements. Therefore the paving structures are flexible. Highwavs and main roads are constructed in asphalt, usually. The remaining pavements are small element pavements: (concrete) paving blocks on roads, streets and industrial and harbour areas; concrete flags on footways, cycle tracks and squares.
As in other Dutch cities and villages the public utility networks are underground. See ref. [1]. Beneath the element pavements they are within reach rather well.

Rotterdam Public Works has the responsibility for the technical design, the construction and the maintenance of the pavements of the public road. Construction is partly executed by our own paviours. See ref. [2].
Until a few years ago the technical design of element pavements was mainly based on experience. Recently methods were developed that are scientific to a larger extent. The Technical University of Delft has developed a design method for the base course underneath a concrete block pavement. See ref. [3]. and [4]. However, a design method for the blocks themselves is still missing. So the technical requirements (strength, dimensions etc.) layed down in standards are based on experience, to a large extend. The paving pattern, the joint width, the joint material, the bedding sand etc. have not yet been standardized in relation to, for example the traffic. The missing link is detailed knowledge of the actual forces on the individual blocks.

Due to the increasing traffic load the thickness of the paving blocks was raised in the past. In Rotterdam normally a block thickness of 90 mm for rectangular blocks sized 211 mm x 105 mm, was used and in case of heavy torsion loads (busstops and harbour area) 120 mm thick blocks were used and still are. Nowadays the need of humanization of labour is realized and priority is given to this item, in Rotterdam. In order to reduce the paviour's hard work one solution is mechanisation of the paviour's trade resulting in less hand work. See ref. [5] , [6] , [7] and [2].
Another solution can be: diminishing the block weight by decreasing its thickness. See ref. [8].
Today a standard thickness of 80 mm is used. But perhaps thinner blocks can meet the requirements in practise, too. To answer this question Rotterdam Public Works carries out a field test. In this experiment in a normally trafficked city street different block thicknesses, varying from 60 mm to 90 mm, have been applied in a concrete block pavement with

a base course.
This report deals with the set-up, the measurements and the interim results and conclusions of this experiment.

2. EXPT SET-UP

In order to get a test representative for the Rotterdam circumstances, an average street which the pavement had to be renewed, was chosen.
It was expected, that mainly the loads due to busses and lorries determine the block thickness.
The location of the test is the Lange Hilleweg, a normally trafficked city street that is part of a bus route. It is not a main road so heavy goods traffic is limited.
Table 1 provides an estimation of the traffic based on counting.

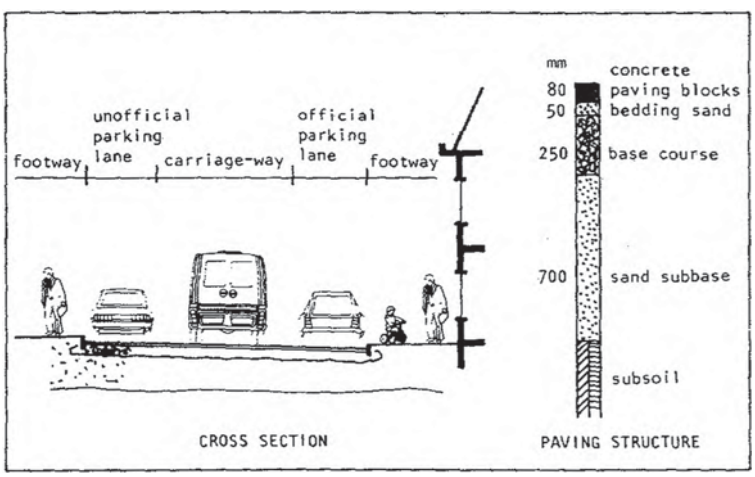
Table 1 Traffic estimation for the Lange Hilleweg

type of vehicle	number of passages per year
passenger car	800,000
bus	35,000
lorry	25,000
van	95,000

An element pavement on a base course of granular material (broken concrete and brickwork) has been chosen, because this type of roadstructure is the appropriate choice for roads and streets with more than minimum traffic.

The cross section in figure 1 gives the lay-out and the composition of the road structure.

Figure 1 Cross section of the road structure



The paving pattern is herringbone bond. The total test area contains four sections with a length of about 30 m each. Successively blocks with a thickness of 60 mm, 70 mm, 90 mm and 80 mm are applied. The adjacent pavement consist of 80 mm thick concrete blocks.

A programme of inspection and measurements was made both for the preparation phase and for the test phase.
In June 1987 the test pavements were constructed.

3. INSPECTION AND MEASUREMENTS

The programme contains three main lines:

- the strength of the blocks;
- the displacements of the blocks;
- cracking of the blocks.

Furthermore some soil investigation has been carried out. The subsoil consist of clay with little sand and peat. It has an elasticity of about 80 MPa.

3.1 Block strength

After delivery the blocks were tested according to the Dutch Standard NEN 7000. One item is the bending strength, tested with a sample of fifteen blocks for each thickness. Table 2 gives the results.

Table 2 Test results (NEN 7000)

block type	60 mm	70 mm	80 mm	90 mm
average block length mm	209.6	210.0	209.2	210.0
average block width mm	103.7	104.0	103.3	104.4
average block thickness mm	62.7	71.0	81.7	91.2
average block bending strength N/mm2	6.8	7.4	8.4	8.3
counted minimum value N/mm2	5.9	6.4	7.0	7.2
required value N/mm2	5.9	5.9	5.9	5.9

The 60 mm blocks were tested for their splitting strength, too. This was done after about two months of the blocks being subjected to traffic. Much cracking of these blocks had appeared and the aim of this examination was to find out whether the broken blocks were statistically fitting in their population. Therefore five broken blocks were subjected to the splitting test and five unbroken blocks were subjected to both the bending test and the splitting test. The results, see table 3, were compared with each other and with the earlier test results. It shows there is no reason for doubting the normal compilation of the population of the 60 mm blocks.

Table 3 Bending and splitting strength of the 60 mm blocks

block nr.	bending strength N/mm2	splitting strength N/mm2	ratio
A	6.8	5.0	1.36
B	7.4	5.3	1.40
C	8.1	5.7	1.42
D	7.7	5.4	1.42
E	7.3	5.7	1.28
average	7.46	5.42	1.38
standard deviation	0.43	0.26	0.05
1	—	5.0	
2	—	5.4	
3	—	5.1	
4	—	5.2	
5	—	5.6	
average		5.26	
standard deviation		0.21	

The splitting test is not standardized in the MEN 7000, but perhaps it gives a better parameter than the bending test, which, in fact, combines bending and shear. Because of this the ratio of bending stress and shear stress varies with the block thickness.

3.2 Displacements of blocks

Immediately after finishing the construction of the trial area measurements haven been carried out. Per section in three lines (two perpendicular and one diagonally) the horizontal and vertical position of six blocks were measured as well as the joint width. These measurements have been repeated at growing intervals. Tables 4 and 5 contain some of the results. It shows that displacements do occur; sometimes the displacements change direction (the horizontal displacements in particular). The largitude of the displacements, however, is limited. Some rutting has occured. The joint width has increased.

Table 4 Displacements of the 60 mm blocks (one line perpendicular) in mm

block nr.	after 3 weeks Δx Δy Δz	after 7 weeks Δx Δy Δz	after 14 weeks Δx Δy Δz
1	+8 -2 +4	-8 0 0	+7 0 +1
2	+7 0 +7	-4 -1 -1	+2 +1 +1
3	+8 -1 +5	-4 +2 -1	+3 -1 0
4	+7 +3 +6	-3 +1 0	+2 +1 +2
5	+7 +2 +2	-2 -1 +4	+3 +4 0
6	+6 0 +4	-4 -2 +2	+2 0 0

Δy - longitudinal
Δx = perpendicular
Δz = vertical (+ - downwards)
Δ is with respect to the former value

Table 5 Average joint width (mm)

block type	Imme diate	after 3 weeks	after 7 weeks	after 14 weeks
60 mm	1.54	2.04	2.29	2.13
70 mm	1.92	1.83	2.67	2.25
80 mm	1.38	1.50	1.96	1.83
90 mm	1.88	2.04	2.42	2.29
average	1.68	1.85	2.33	2.13

3.3 Inspection

Inspection is especially accentuated to the expected cracking of the blocks. Because to be sure that one has achieved the minimum value for the block thickness, thinner blocks must prove their Inapplicability.
Inspection provides a global impression of the behaviour of the pavement, too. The section with the 60 mm blocks showed cracking of blocks almost immediately. After 2 weeks the broken blocks were counted. In the 14th and the 23rd week it was done again. See table 6.

Table 6 Percentage of broken blocks

Block type	60 mm	70 mm
After 2 weeks	2.1	0.35
After 14 weeks	6.4	0.54
After 23 weeks	6.9	0.90

It shows that cracking of both the 60 mm and the 70 mm blocks is still going on. The percentage of broken 60 mm blocks is substantial. The 70 mm blocks show cracking too, but to a smaller extend. The 80 mm and 90 mm blocks have no cracking at all.

The plane of fracture is more or less perpendicular in the middle of the blocks. Most cracking occurs in the tracks.

4. INTERPRETATION AND CONCLUSIONS

As already mentioned, especially the largitude of the loading is held responsible for the cracking of the blocks and not the large number of loads. This in contrast with the design method for asphalt pavements and for the base course, in which the large number of loads is essential.
However the loading on an individual block depends upon a large number of parameters. In

table 7 the most important ones are listed.

Table 7 Loading parameters

- sizes of the block
- shape of the block (e.g. rectangular)
- elasticity of the block
- paving pattern and lock-up
- level of the block compared to the surrounding blocks
- joint (width and material)
- bedding sand (height and material)
- wheel load
- speed of loading
- load transfer

Only a few of these parameters can be filled in more or less accurately. For some of them there is a global idea of their relation. Others still can not be indicated at all.
Therefore in a test like this only a comparison in practise can be made. The basic assumption is that when the blocks do not crack in the first period of 6 to 12 months, they will stand for the rest of their lifetime (20 years?). Because there is a good chance of at least a few blocks being subjected to their critical load in the first period.

The fact of so much cracking of the 60 mm blocks within the first few months is enough evidence that they are not applicable for this traffic loading in this particular paving structure. The 90 mm and 80 mm blocks have no cracking, so their applicability can be concluded.
The cracking of the 70 mm blocks can not be neglected. Time will show whether this cracking reaches an unacceptable level.
With a view to the results so far one may assume that the minimum value of the standard block thickness will be between 70 and 80 mm. Other parameters as listed in table 7 will be decisive for the exact value, too.
During a long period a block thickness of. 90 mm was used in Rotterdam. Also anticipating the present experiment the block thickness has been reduced to 80 mm. This size is used more commonly in The Netherlands. For special applications 120 mm thick blocks are still available.

5- CONTINUATION

This experiment will be continued for a longer period in order to study the further behaviour of the pavements. The frequency of the measurements will be decreased.
If the cracking of the 60 mm blocks will reach a high level, this section will be renewed, perhaps with 70 mm blocks in a adapted pavement structure, if desired.
Still the striving remains for a more sophisticated design method for the paving blocks themselves, in which the most important parameters are taken into account. During the former conference in Delft in 1984 some promising efforts were presented [9]. To the development of this design method Rotterdam Public Works is willing to bring in its part.

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