The use of concrete block pavements for highways

by S. Lekso

Statens Vejlaboratorium, Denmark

Introduction

Concrete blocks laid in an interlocking system are becoming a common type of pavement in Denmark for pedestrian areas, cycle paths and open spaces. In these areas concrete blocks have almost ousted traditional flagstones and to some extent asphalt pavements. This is due to (a) simple laying, (b) great resistance to overloading, (c) little maintenance, and (d) simple re-laying after excavations.

Another main field of application is for quays and industrial areas, both indoors and outdoors.

As regards roads proper, concrete blocks are used only to a limited extent for residential streets, roads with a maximum speed of 30 km/h and for bus bays.

In the spring of 1975 the Cement Factories' Technical Information Office set up a working group with the task of analysing the possible application of this type of pavement to motorways and other major roads. In its report it is concluded that it should be possible, technically and economically, to introduce the pavement type on primary roads with fulfilment of the existing demands on safety and long life.

This resulted in a decision by the Road Directorate, in concert with Viborg County, to test concrete blocks as a road pavement on main road 348, south of Viborg.

TABLE 1: Division of the test road

Test section	*Length (m)*	*Pavement type*
A	200	Asphaltic concrete, reference stretch
B	200	Salviacim
C	200	KB-concrete blocks
D	200	FiSK-concrete blocks
E	200	SF-concrete blocks
F	200	IBF-concrete blocks
G	100	Asphaltic concrete, reference stretch

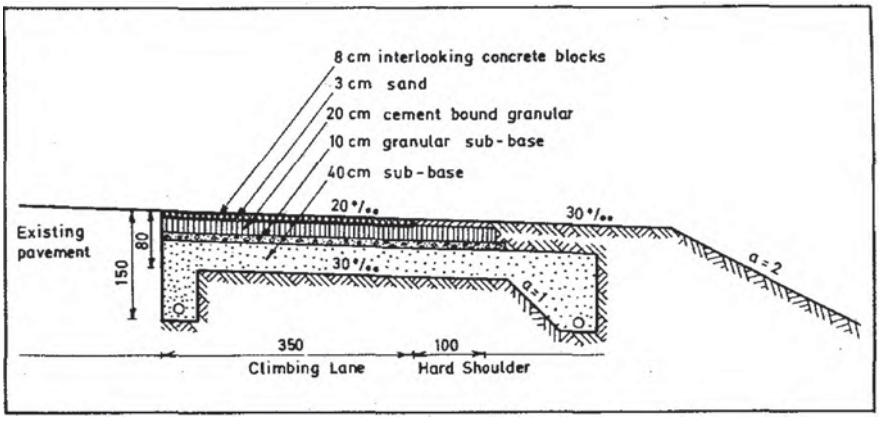


Figure 1: Standard cross-section of test pavement. Dimensions in cms.

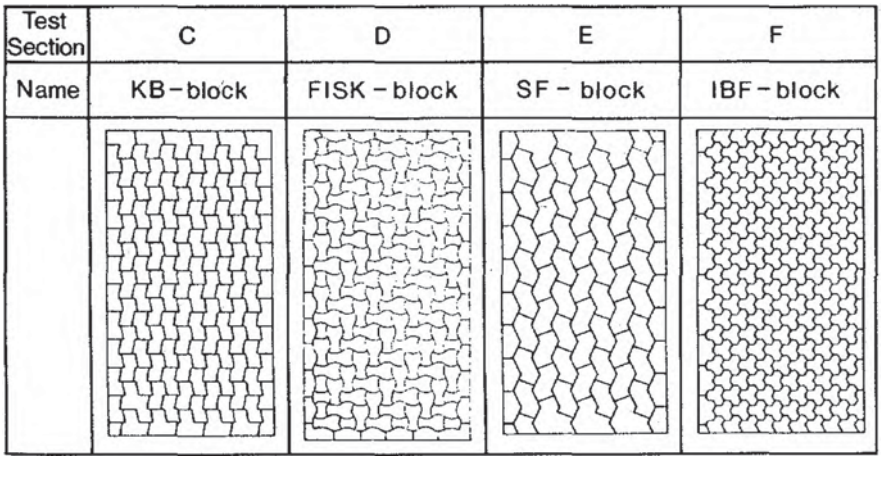


Figure 2: Interlocking systems possible with the different blocks.

Construction

The test road was constructed in the summer of 1977 and opened to traffic on 10 October 1977. The test road is built as a 1.3 km long and 3,5 m wide climbing lane up a hill with a longitudinal fall of 5%. All traffic which cannot maintain a speed of 70 km/h is ordered to use the climbing lane.

The test pavement is a one-sided extension of the existing pavement. It is built up of 8 cm of concrete blocks, 3 cm of sand, 20 cm of cement bound granular, 10 cm of granular sub-base material and 40 cm of sub-base sand (Figure 1).

The test road has been divided into seven test sections (Table 1) consisting of four types of interlocking concrete block paving, two reference stretches with asphaltic concrete and a test stretch paved with Salviacim. Salviacim is an open asphaltic concrete which has been treated with laitance. The interlocking systems of the individual types of concrete blocks are shown in Figure 2.

Materials

The cement-stabilized wearing course is factory-made of granular sub-base material type 1 + 8% of ordinary Portland cement. A compressive strength of about 20 MPa of laboratory-stored cylindrical test specimens were measured after 7 days.

The concrete blocks were tested for compressive strength and showed an average strength of 76-81 MPa characteristic values for the types of concrete blocks of 65-77 MPa. The aggregates used for the concrete blocks vary as both marine aggregates and local gravel were used.

The laying course sand is natural pitsand with a grading curve as indicated in Table 2.

The asphaltic materials used comply with the conditions of supply in force in Denmark.

Laying

The concrete blocks were hand-placed according to the following procedure:

1. The sand was spread and compressed by a roller.
2. The sand surface was levelled with

a beam drawn on levelled sectional irons.

3. The concrete blocks were laid in an interlocking system.

4. The joints between the blocks were filled with sand of the same quality as the levelling sand.

5. The sand on the outside of the border blocks was removed and replaced by a "triangle" of bitumen macadam which was tacked to the underlying layer.

6. The blocks were vibrated by a vibrating plate and a small tandem wheel roller.

As the triangle of bitumen macadam had become loose in several places during the vibration, it was removed before the laying of the final asphaltic pavement on the sides.

Traffic and climate

On the test section of the main road the average annual daily traffic amounts to 3,200 vehicles in each direction. A count shows that 70% of the lorries and 10% of the passenger cars, or a total of 27%, uses the climbing lane. The calculated number of 101 standard axles per 24 hours amounts to 290 in the climbing lane, ie. 635 standard axles of 8 t.

The climate in Denmark is strongly detrimental to pavements, as in long periods during spring and autumn we have thaw in the daytime and frost in the night. At the same time there is extensive use of de-icing salt to prevent slippery roads. Thus approx. 1 kilo of salt per square metre is spread during wintertime.

Pavement qualities

An extract of measured and recorded pavement data is stated below.

Evenness in the longitudinal direction

The evenness in the longitudinal direction has been tested by both a Viagraf and a bump integrator. The first measurements showed that the ordinary demands on the wearing course of roads with a design speed below 90 km/h were not met. Later measurements, after a period of use of two years, still showed an unsatisfactory evenness but there is a tendency for the most uneven pavements to become more even, as is shown by the results of the bump integrator measurements in Table 3.

Transverse profile

The pavement surface of the climbing lane was levelled at two cross sections within each test section at a distance of 20 cm. Additionally, a Permascope was used to measure the distance between the surface of the pavement and a strip of aluminium foil fixed to the base of cement bound granular material.

TABLE 2: Grading of sand under and between the concrete blocks

Sieve size (mm)	0.064	0.125	0.25	0.5	1.0	2.0	4.0	8	16
Percentager by weight passing	0.5	3.0	17.5	47	82	93	96	98	100

TABLE 3: The results of the bump integrator measurements at speeds of 32,40 and 60 km/h respectively at the opening of the road and in 1979 after two years of traffic. The demands are below 240 at 32 km/h.

Speed	*year*	*A*	*B*	*C*	*D*	*E*	*F*
32 km/h	1977	188	145	291	263	343	504
	1979	165	140	305	292	305	406
40 km/h	1977	176	126	252	231	389	377
	1979	152	115	229	242	267	356
60 km/h	1977	138	101	192	177	227	381
	1979	127	101	178	178	216	267

TABLE 4: Average values of the skidding resistance measured by the Stradograph

Test section	*20 km/h*			*60 km/h*			*80 kmjh*		
	1977	*1978*	*1979*	*1977*	*1978*	*1979*	*1977*	*1978*	*1979*
A	1.09	0.80	0.94	1.03	0.80	0.81	0.99	0.79	0.77
B	1.02	0.81	0.96	0.95	0.77	0.76	0.92	0.74	0.72
C	0.76	0.60	0.75	0.57	0.46	0.52	0.48	0.46	0.47
D	0.77	0.58	0.73	0.67	0.45	0.50	0.62	0.46	0.48
E	0.73	0.66	0.78	0.65	0.54	0.55	0.58	0.53	0.54
F	0.69	0.62	0.74	0.49	0.49	0.50	0.45	0.47	0.47
G	1.04	0.79	0.91	1.03	0.80	0.81	0.97	0.79	0.78

Test section	S	*C*	*D*	*E*	*F*	*G*
1977	70	67	66	65	66	—
1979	60	52	49	52	49	58

The measurements were made in 1977 and 1979.

From the measurements it appears that no wheel tracking was found in any of the sections paved with concrete blocks whereas up to 10 mm of wheel tracking was observed on one of the reference stretches paved with asphaltic concrete. Permascope measurements of the thickness show that the thickness of the layer of sand has been reduced to about 2 cm after two year's use.

Skidding resistance

In 1977, 1978 and 1979 the skidding resistance was measured by means of the National Road Laboratory's Stradograph at speeds of 20, 60 and 80 km/h' respectively. This measuring vehicle measures the skidding resistance continuously by means of an oblique unprofiled measuring wheel.

The average values of the different test sections appear in Table 4.

The results show a major fall in the skidding resistance during the first year, but the level is still satisfactory, however, since a satisfactory value is considered to be 0.4.

Texture depth

At two cross sections of each test section the texture depth was measured according to the sand patch method and the skidding resistance by means of a portable skidding resistance tester according to the directives of Road Note 27. The measuring of the texture depth shows a constant level of 0.6-0.7 mm. The pendulum measurements do not show any great differences from one

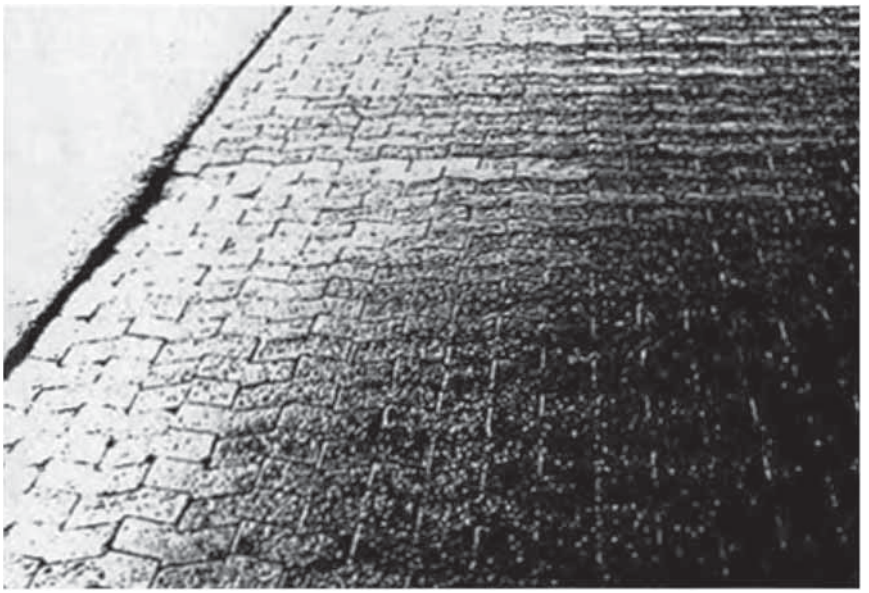


Figure 3: Close-up of pavements showing settlement.



Figure 4: General view of the paved area of the test road.

type of concrete block to the other although a major fall from the open–ing of the road to the second measure-ment two years after was recorded (Table 5).

Inspection

As early as December 1977 deflection cracks from the cement bound gran–ular layer in the Salviacim pavements were observed after two months.

The concrete block pavements showed satisfactory durability and stability. The few cracked blocks are due to faulty laying. There are, however, to be seen a number of transverese settlements of the con–crete blocks across cracks of shrink–age in the cement bound granular. These are probably due to erosion and pumping of the laying course sand. Also, sporadic settlements caused by the laying technique with insufficient support from shoulders are found close to the edge of the road pavement (Figure 3).

TABLE 6: Estimated mean values for joint opening in mm

Test section	C	D	E	F
in wheel tracks	3	6	2	4
Outside the wheel tracks	2	4	2	3

A spot test measurement of the joint opening shows a slight tendency towards an opening of the pattern in the wheel tracks and a correspond-ing compression of the block out–side the tracks. Some estimated mean values for the individual block types are shown in Table 6.

The depth between the blocks down to the sand was measured at the same time to approx. 10 mm in the ruts and 5 mm between the wheel tracks. A close-up view of the settlement and a general view of the pavement are shown in Figure 3 and 4.

Conclusions

From the point of view of construc-tion, bitumen bound sand or cement mortar should be used (or the levelling layer under concrete blocks laid on concrete or cement bound granular material. This is especially important on roads with a severe longitudinal fall and crossfall like the test road.

In general the test pavement has behaved well. It is remarkable that no tracking has been observed. It is suprising, however, that the skid–ding resistance fell so quickly from its high starting level to the acceptable level now recorded.

Even in the case of a thicker bitu–men bound levelling layer, it is doubtful whether the pavement can attain an evenness and driving com–fort which makes it generally suited as pavement on main roads and motorways, but it can be expected to find extensive use in urban areas with lower speed limits (60km/h).