WEAR-RESISTANT CONCRETE BLOCK PAVING AT GOTSU TUNNEL IN NIIGATA PREFECTURE

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SUMMARY

Road surfaces suffer major damage during winter and cold weather due to the use of studded tires and steel chains. In particular, road surfaces inside tunels, because they are not covered by compacted snow, suffer direct damage and their surface wear is considerable.

In the past, road repairs in tunnels in Japan relied mainly on overlay work using asphalt materials, however, this method always posed the problems of wear resistance, precision of work, clearance, etc.

The author and his collaborators have recently succeeded in developing a concrete paving block with twice wear resistance or conventional concrete, and have confirmed its characteristics by applying the new product on road surfaces repair work on the Gotsu Tunnel on the heavily traveled National Highway No.8 in Niigata prefecture.

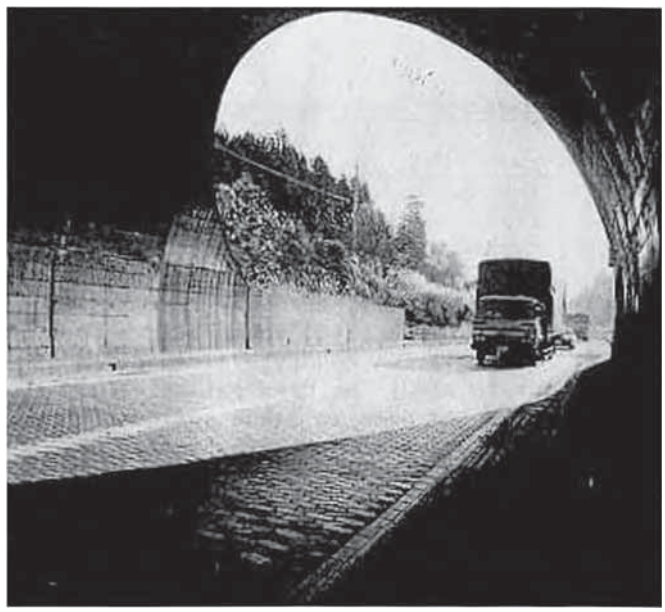
This report describes the materials, the mix proportions, casting conditions and the results of studded tire wear resistance test performed in the laboratory. It also discusses the evolution of the wear resistance of the concrete block under the heavy traffic conditions of the tunnel and that of the profile of the road surface.

1. INTRODUCTION

Roads in snowy regions, especially those in tunnels, are heavily damaged by studded tires and tire chains due to the absence of compacted snow. Worn roads are normally overlayed with asphalt materials; the problems are that overlay work must be repeated every winter and (that tunnel) clearance lessens as a result of continual overlaying.

To solve these problems, the author and his colleagues have developed an interlocking block which is simple to manufacture and which is twice as wear-resistant as conventional concrete. A test pavement was constructed to confirm the wear resistance of the concrete blocks on the road surface of National Highway No. 8 in Gotsu Tunnel in Niigata prefecture in November, 1984.

Photo - 1 Outer aspect of Gotsu Tunnel



2. OUTLINE OF GOTSU TUNNEL

Gotsu Tunnel, part of the route of National Highway No. 8 along the Japan Sea coast, is a 650-meter road tunnel located in Joetsu city in Niigata prefecture. Gotsu Tunnel is shown in Photo 1. Joetsu city in known as a heavy snow zone. From early December to late March in particular, clouds over the Japan Sea are pushed into this area by the Okhotsk high atmospheric pressure zone, and there can be snowfalls of more than 120cm in one day. National Highway No. 8 in this zone is the main road running along the Japan Sea side of the main island. Since the construction of bypasses is physically impossible, the traffic on this road is naturally increasing to very high levels. For instance, the average one-lane traffic per 24 hours reaches 14,500 vehicles in which rate of large sized automobiles is as high as 34%. Therefore, the total number of vehicles passing this road in winter reaches about 2,000,000 cars equipped with studded tires or tire chains.

A sectional view of the tunnel is shown in Fig. 1.

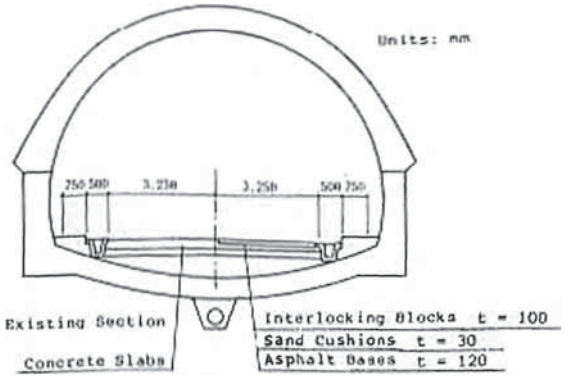


Fig. 1 Section of Gotsu Tunnel

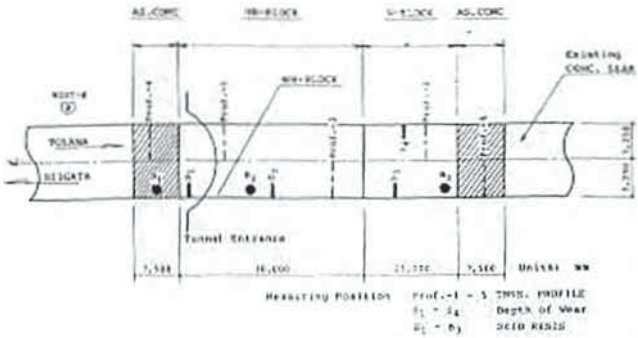


Fig. 2 Pavement Slabs and Measuring Position

3. TEST PAVEMENT USING WEAR RESISTANCE BLOCKS

3-1 Pavement Plan

The test pavement has been constructed for a road surface section, 6.5m wide x 60m long, near the tunnel entrance. The plan is shown in Fig. 2. The marks HR-block, N-block and WH-block indicate, respectively, the wear resistance blocks, normal blocks, and white blocks for marker. The existing concrete pacement, a 25cm thick concrete slab, has been extensively damaged as it has been in place for over a decade. The test was carried out adter 25cm thick concrete slabs were removed. 12cm thick asphalt base was laid, on the sub-base, and (a) 3cm thick sand cushion and 10cm thick concrete blocks were laid on the asphalt base. The section is shown in Fig. 3.

Existing Concrete Slabs Block Pavement

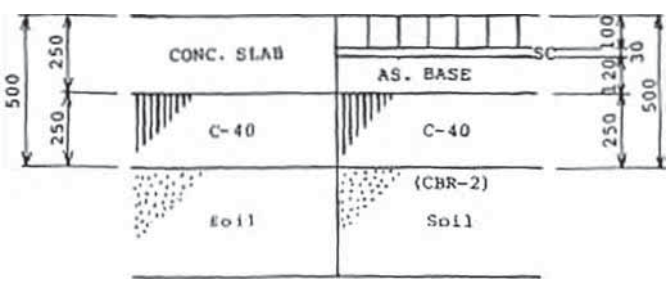


Fig. 3 Section of Pavement

3-2 Manufacture and characteristics of wear resistant concrete blocks

A) Manufacture of blocks: The use of ferronickel slag as an aggregate and super-water reducers is characteristic of the manufacture of wear resistance concrete blocks, and blocks are manufactured by Hess machines. Accordingly, new investment is not needed and economical production of high wear resistant concrete blocks is enabled. The shapes and sizes of blocks are shown in Fig. 4.

B) Performance of concrete blocks: The standard of manufacturing and the test results are shown in Table 1. The average compressive strength of HR-block is 1,163 kgf/cm^2, which is 1.71 times that of an N-block. A wear test was carried out with a rotary wear test machine as shown in Photo 2. Test conditions are shown in Table 2. The relationship between number of rotation and depth of wear is shown in Fig. 5. The average wear depth of HR-blocks tested on the turntable at 117,000 times was 1.1mm, equivalent to about half that of normal paving concrete and a quarter that of dense-grade asphalt concrete. Consequently, HR-blocks proved to be very high in wear resistance.

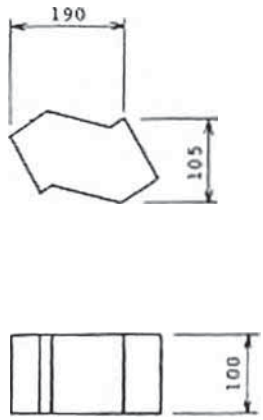


Fig. 4 Shape and Dimensions of Block

Photo - 2 Wear Test Machine

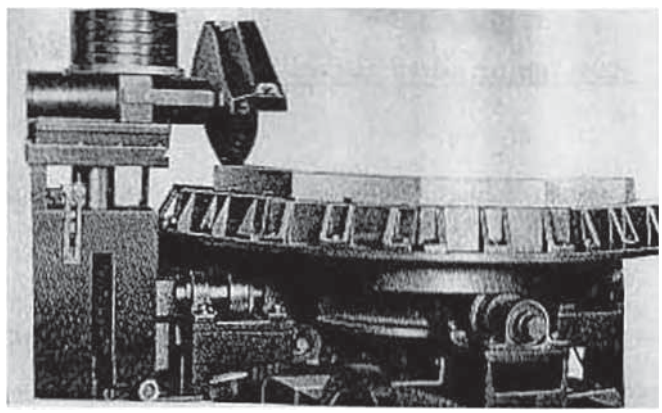


Table 1 Quality Stadards and Test Results of Blocks

Block	Standard Manufacturing Value			Test Results		
	Thickness	Compression Strength kg/cm2	absorption (%)	Thickness	Compression Strength kg/cm2	absorption (%)
N	100±3	more than 600	less than 5	102	678	4.98
HR	100±3	more than 1000	less than 3	99.8	1163	7.52
WH	100±3	more than 600	less than 5	101	719	5.00

Table 2 Test Conditions

Wheel load	W-150 kg
Speed	30 km/hr
Tire	Studded tire (YOKOHAMA ALPEN SNOW-821)
Abrasion volume	Dial gauge Average of three traverse lines
Room Temperature	18 - 21 °C in wet condition

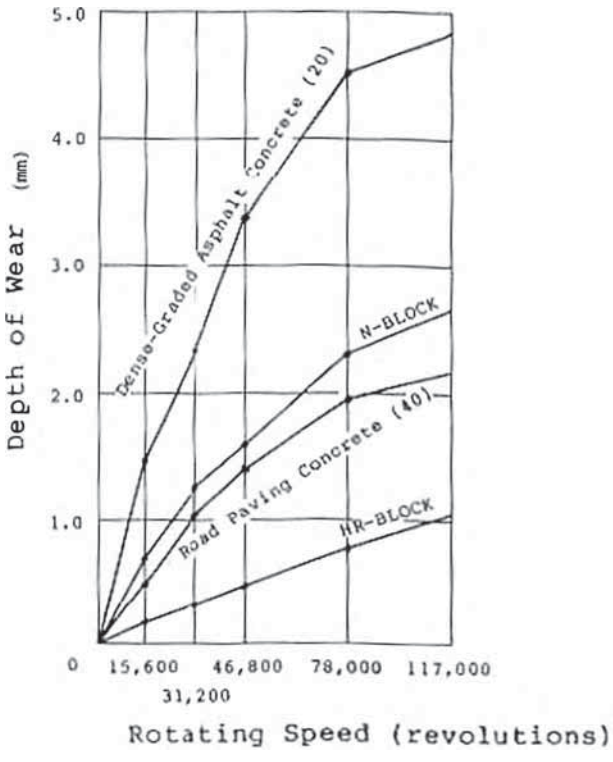


Fig. 5 Results of Wear Test

Photo - 3 Laying of Blocks



3-4 Results of inspection

A) Profile of the road surface: The profiles of traverse lines (P-1 on HR-block pavement, P-2 on N-block pavement, and P-5 on asphalt pavement) are shown in Fig. 2. Straight-edges were used to measure these profiles. Fig. *6* shows profile change of road surface. On the HR-block paved road surface, maximum sinking measured 21mm after the first winter and 50mm after the second winter. For the asphalt paved road surface, maximum sinking was 14mm after the first winter and about 40mm after the second winter.

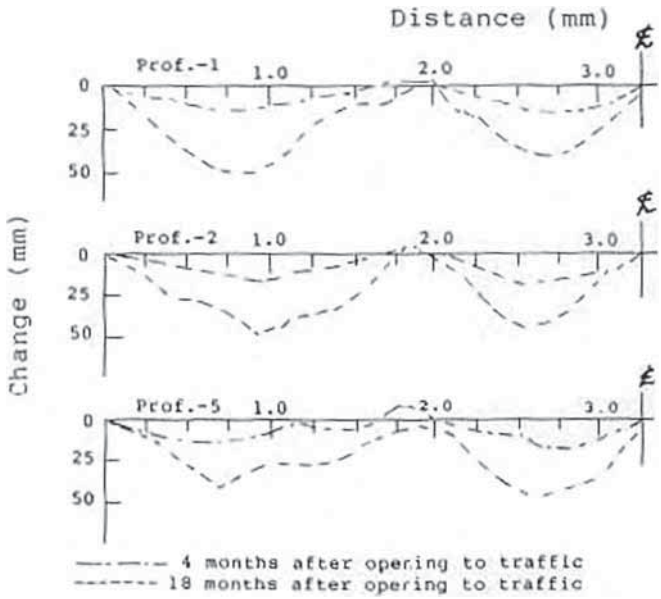


Fig. 6 Changes in Profile

3-3 Pavement work

Considering the busy traffic and narrow space in the tunnel the work was performed between 7:00 p.m. and 7:00 a.m. allowing a single file of traffic to pass. Four days were spent for the whole process from removal of existing concrete to the laying of all the new materials The progress of this work is shown in Photos 3.

It was considered that the greater unevenness of the block pavement compared to the asphalt pavement was mainly caused by the consolidation and flow of sand cushions. As clarified from the results of block wear measurement (see the next paragraph), the wear of the blocks themselves is rather small. The sinking of the asphalt pavement, however, is considered to be mainly due to wear.

B) Amount of wear: The amount of wear of the concrete blocks, from S-l to S-4 as shown in Fig. 2, was measured by sampling five pieces for each site. The measurement conditions are shown in Photo 4, and the results in Table 3.

The average amount of wear of the HR-blocks after first winter was 2.8mm; that of the de-blocks was 6.1mm. This indicates that the wear resistance of the HR-blocks is more than twice that of the N-blocks. Considering that the maximum depth on asphalt pavement was 14mm, the above shows that the resistance of the HR-blocks is excellent.

Table 3 Wear Depth of Blocks

Measuring position	Block Type	Wear Depth (nun)	
		1985.3	1986.6
S-1	HR	3.2	4.6
S-2	HR	2.4	4.2
S-3	N	6.0	9.2
S-4	N	6.0	9.0

Photo - 4 Measurement of Block Wear



C) Skid resistance: The changes in skid resistance of the road surface were measured using a portable skid meter, ASTM-E303-66T. The locations measured, from B-l to B-3, are shown in Fig. 2 the results are shown in Table 4. The skid resistance of block pavement was a little lower than that of asphalt pavement.

Table 4 Skid Resistance Measurement Results

	Skid Resistance Measurement Results (B.P.N)			
	Immediately after paving		1985. 3. 19	
	Dry condition	Wet condition	Dry condition	Wet condition
B-l (HR)	84	61	87	63
B-2 (N)	86	67	09	72
B-3 (AS)	91	68	93	75

D) Number of broken blocks: The number of broken blocks after the first winter is shown in Table 5. The numbers, although different for the different lanes, are very small: 0.27 percent for the HR-blocks, 0.47 percent for the de-blocks and 0.42 percent for the white blocks.

Table 5 Rate of Breakage

		Number of blocks with corner breakage	Number of blocks with rough surface	Rate of breakage (%)
Up Lane	N	3	13	0.38
	HR	0	7	0.34
	WH	2	2	0.47
Down Lane	N	24	0	0.56
	HR	2	2	0.19
	WH	1	2	0.36

4. REPAVING

In the investigative report of June, 1986, it was shown that a considerably uneven surface was produced on the concrete block pavement. The entire surface was therefore repaved in September, 1986. This section of block pavement was investigated to clarify the cause of the uneven road surface. No unevenness or cracks were on the asphalt base, so that the cause of the uneven road surface proved to be the consolidation and flow of the sand cushions.

A section of block pavement is shown in Photo 5. The following steps have been taken so as not to repeat the previous errors at repaving.

(1) Increasing the height of the asphalt base and making the average thickness of the sand cushions 2cm after compaction.
(2) Strengthening the sand cushion by mixing in 5% cement.
(3) Boring holes in the gutter and installing ceramic filters into the holes to facilitate rapid drainage.
(4) Mixing cement and crushed stone dust, to the extent of *5%* each, into the sand in the joints between blocks to prevent rain water from seeping into the area underneath the blocks.

After these steps were taken and after one winter had passed, from the results of the investigation made in June, 1987, the average depth made by tires on the down lane was measured at 10.9mm and that of the up lane at 5.4mm, less than half the measures of the previous year. Also, the average amount of wear in a sample of ten HR-blocks was 1.35mm. Furthermore, it was confirmed that the consolidation of sand cushions can acceptably decrease the occurrence of the uneven road block surface resulting from heavy traffic, and sufficiently minimize the wear of blocks.

Photo - 5 Section of Block Pavement



5. CONCLUSION

The author and his colleagues have developed wear-resistant concrete blocks that may be manufactured using normal block machines and have evaluated the performance of these blocks in a test pavement in a tunnel encountering the most severe conditions - i.e., heavy traffic in a high snowfall region.

A summary of this investigation is as follows:

1) Extremely high strength is obtainable with concrete blocks containing ferronickel slag as the aggregate, so that higher wear resistance can be obtained. According to the test data from the laboratory, the wear resistance of this block is twice that of normal concrete for pavements and four times that of asphalt concrete.
2) The test pavement evaluation in the tunnel indicated that the amount of wear of HR-blocks is about half that of N-blocks at 1/4 - 1/5 that of asphalt pavement.
3) When concrete block pavement work is performed on a road, as on this site, with bus traffic and the high occurrence of heavy vehicles, thorough consideration of the quality, thickness, compaction and drainage of sand cushions is absolutely essential to extending the life of the pavement.