CONCRETE BLOCK PAVING - FULL SCALE FIELD EXPERIMENTS IN INDIA

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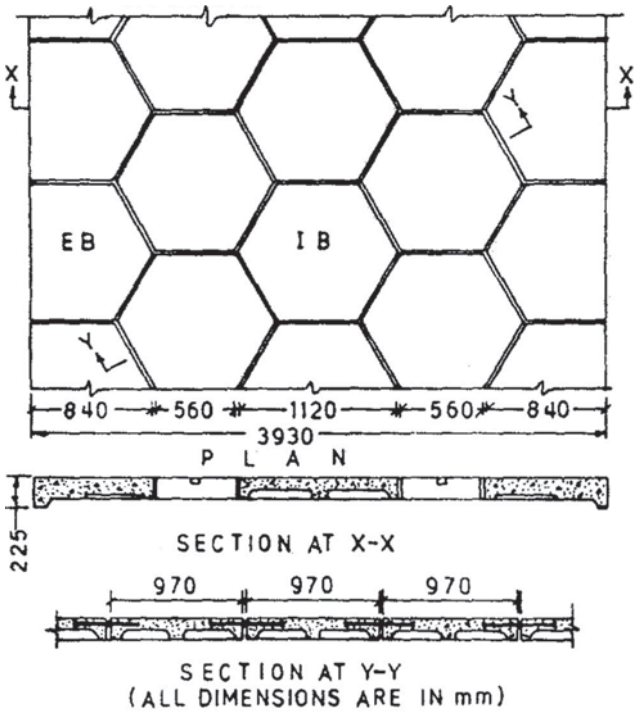
Good quality road construction materials, including water, are not easily available within short leads in the desert areas of Rajasthan in India. Hence, prefabricated concrete blocks of hexagonal and pentagonal shapes with ribs and hollows underneath were designed and experimentally evolved as an alternative method of paving. The blocks are produced centrally, transported to the site, paved on compacted dry sandy subgrade, interconnected through dowel-sleeve system and seated by vibration. The paper summarises the field experiments involving construction of three test sections and performance study of two of them.The study indicates that, after tolerable initial settlements, the structures have attained an equilibrium stage and are giving satisfactory performance. Some edge spalling was observed at the first test section and maintenance involved replacement of two damaged blocks.

For this type of construction, water is required only for production of blocks and, in comparison with conventional construction, transportation of materials is considerably reduced. Also, maintenance cost is likely to be much lower than that for flexible pavement. Economic evaluation of the technique has also been included. In the case of longer leads for key materials, which is a normal occurance in the desert areas, the technique is found to be economically viable.

1. INTRODUCTION

Road construction in the desert regions of Rajasthan in India generally involves long haulage of construction materials, use of water in large quantities for wet compaction of different layers, and fuel for heating bitumen. The Central Road Research Institute (CRRI), New Delhi, has developed an alternative paving system based on prefabricated plain concrete blocks which can be produced in a factory set-up under proper quality control, transported to the paving site and assembled directly on the compacted dry sandy subgrade, thus forming a complete pavement by itself. The prototype of the new pavement system (Fig.1.) developed

FIG. 1. SKETCH SHOWING CONFIGURATION OF PRECAST BLOCK PAVEMENT SYSTEM.



for medium intensity of traffic (upto 200 commercial vehicles per day) consists of precast concrete blocks of hexagonal and pentagonal shapes which are plane on top and ribbed at the bottom. A detailed report of the laboratory work leading to the development of the prototype has been published elsewhere(1). A brief report of the laboratory work and additional findings appeared in the proceedings of the Second International Conference on Concrete Block Paving held at Delft (2). Two experimental sections were constructed on selected routes in the Rajasthan desert in June, 1985 and November, 1986 in collaboration with the Border Roads Organisation of India. Presented in this Paper are the various aspects of mix design, production, construction and quality control, and initial performance of the sections. A third test section was constructed in Bikaner district in October, 1987 in collaboration with Rajasthan Public Works Department.

2. MATERIALS AND MIX DESIGN

The cement concrete mix was worked out to the light of materials available. Gap grading was indicated in this case(3). Ordinary Portland cement with specific gravity of 3.18 and 7-day and 28-day strengths of 330 kg/cm. sq. and 435 kg/cm. sq. respectively, was used. The aggregates used were 20 mm single size crushed aggregate and natural river sand of fineness modulus 2.8 (4). The combined gap grading curve, indicated two gaps from 2.36 mm to 10 mm. The mix was designed for 28-days flexural strength of 50 kg/cm.sq. As vibration compaction was to be used in production, slump was kept close to 0-10 mm. The mix proportions are given below :

Cement	Sand	Coarse Aggregate
1.00	1.36	2.64

Water-cement ratio : 0.34

Aggr.-cement ratio : 4.00

Sand Content : 34% by weight of total aggregate.

Cement content: 468 kg/m.cu.

The 28-day flexural strength achieved for 100 mm x 100 mm x 500 mm beams was 50 kg/cm. sq. The corresponding compressive strength of 100 mm cubes was 495 kg/cm. sq.

3. PRODUCTION OF COMPONENTS

The materials, equipment and manpower resources required for production of blocks were arranged by the Border Roads Organisation. Fifteen special moulds were fabricated and a suitable casting shed and curing tanks were constructed, as shown in Photo 1. A field laboratory was also set up at the casting yard. Weigh batching was adopted for preparation of concrete. The lubricated moulds, fitted with dowels at appropriate places, were filled with green concrete, giving adequate surcharge for full compaction. Compaction of lower layers was effected by using a needle vibrator. The top surface was compacted and partially levelled by using a pan vibrator (with modified pan). Final levelling was done with a wooden straight edge. Rods were embedded at appropriate locations for provision of holes over the hollows. Surface finish was provided with a coir brush. The rods were removed after initial set of cement and initial curing was effected by wet gunny bags. The blocks were demoulded after 24 hours and the exposed portions of the dowels were coated with grease. They were then transferred to the curing tanks and ponded curing was provided, as shown in photo 2.



Photo 1: A view of the casting yard and moulds used for production of blocks.

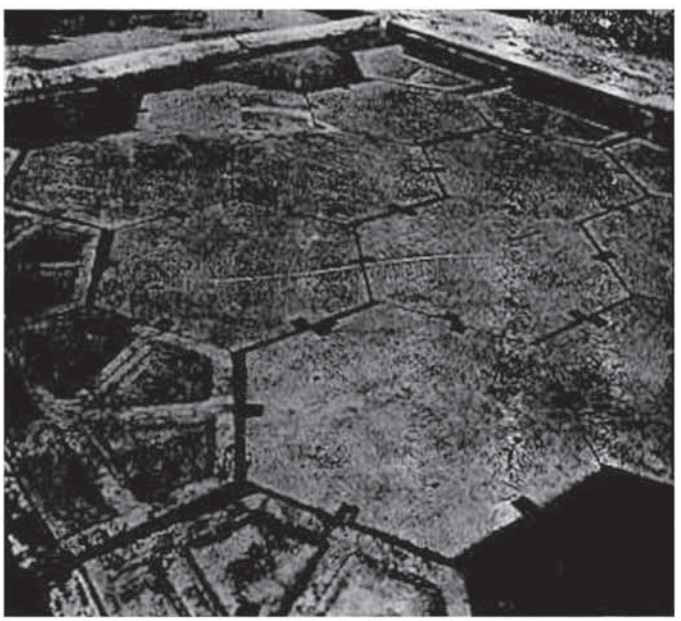


Photo 2: Ponded curing of blocks.

4. QUALITY CONTROL

For quality control testing, 100 mm cubes and 100 mm x 100 mm x 500 mm beams were prepared. Method of compaction adopted for the specimens was identical with that for the blocks. The ambient temperature during the production period was in the range of 8-26°C during winter and 20-41°C during summer. Given in Table 1 is the statistical analysis of the test results. The results indicate that the flexural strengths achieved

TABLE 1. STATISTICAL DATA ON QUALITY CONTROL.

	NO. OF SAMPLES/ AGE IN WEEKS	MEAN STRENGTH (kg / cm^2)	STANDARD DEVIATION (kg / cm^2)
FIRST TEST SECTION			
COMPRESSIVE STRENGTH	50/4	470.0	29.6
	10/4 (FEB.85)	415.0	24.3
	(50+10)/4	460.0	36.6
FLEXURAL STRENGTH	4/6	49.0	-
	13/ 9	52.0	4.6
	13/19	65.0	4.3
	11/22	68.0	7.8
SECOND TEST SECTION			
COMPRESSIVE STRENGTH	20/4	490.0	26.6
	14/6	495.0	23.7
FLEXURAL STRENGTH	21/4	53.0	3.6
	12/7	55.0	3.4
	10/12	55.0	2.4
	7/14	56.0	2.3

NOTES :- 1. ONE SAMPLE = AVERAGE STRENGTH OF THREE TEST SPECIMENS

2. COEFFICIENT OF VARIATION OF 10% WAS ASSUMED AT THE DESIGN STAGE.
3. ACCEPTED TOLERENCE LEVEL = 6.7 % (t = 1.5)

were compatible with the 28-day design flexural strength. The compressive strength tests were conducted for comparative purposes. The results indicate that generally good quality control was achieved at the job. The quality had suffered some set-back during the first half of February, 1985, when the mean 28-day compressive strength for ten consecutive test results dropped to 415 kg/cm.sq. The blocks produced during this period were closely examined and the few visually defective blocks were separated. The rest of the blocks were used for paving.

5. CONSTRUCTION OF TEST SECTIONS

5.1 First Test Section

The site for the first test section is in an undulating sandy terrain, with shallow embankment of 0.5-1.0m height. The blocks were transported to the site. The subgrade was prepared by spreading the local dry desert sand and by compacting the same in two layers of 30 cm each by using a light vibrating plate compactor with an impact force of 2000 kg and pressure of 0.6 kg/cm.sq. After preparing and levelling the subgrade, the edge lines were demarcated and mild steel sheets were spread at appropriate places on

the subgrade for serving as a temporary platform. The blocks were brought by trolleys as well as by manual handling and sleeves were fitted on dowels. Contours were made In the sand to accommodate the extra-deep outer edge of the Edge Blocks and the blocks were laid in position, using crow bars for support (Photo 3). Fine adjustment of the



Photo 3: Paving of blocks.

blocks was effected by a wire and crow bar. After adjusting for level and evenness, the pairs of dowels were connected by screwing the sleeves with appropriate tools. After paving the section, a layer of clean desert sand was spread on top of the surface and the plate vibrator was operated over it. Sand was also poured through the holes into the hollows. The recesses accommodating the sleeves were filled with lean concrete and moist cured. Shoulders were prepared with local sand and a thin layer of locally available gravelly soil was spread on top. Construction was completed in June, 1985 and was immediately opened to traffic.

5.2 Second Test Section

The second test section is located at the base of a sand dune of about 25 m height. This was done with a view to studying the long-term effects of wind/water erosion, sand dune movements, etc. on the performance and use of the pavement. The embankment formation was prepared by cutting the base of the sand dune and filling the depressions. The formation of maximum height of 7 m was left for natural densification and use by construction traffic for about 6 months before starting construction. The sandy subgrade was prepared in two layers. Initial compactive effort was applied by the plate vibrator. Final compaction was done by spreading mild steel sheets and giving five passes with a 3.5 tonne vibratory roller. Modulus of subgrade reaction of the subgrade was 4.1 kg/cm. cu. The subgrade was leveled and initially only the Interior Blocks were assembled on the subgrade in the required pattern and interconnected through dowel-sleeve system. A layer of clean dune sand was spread on top and the blocks were seated first with the plate vibrator and then by using the vibratory roller, as seen in Photo 4. This



Photo 4: Seating of Interior Blocks.

was followed by paving and seating of the Edge Blocks. Filling of dowel gaps and construction of shoulders were done as in the previous case. The completed section was opened to traffic in December, 1988.

6. TRAFFIC & PERFORMANCE EVALUATION

Performance of the two test sections is being monitored regularly. Periodic field measurements for determination of transverse and longitudinal profiles, irregularities under 3 m straight edge, surface deflections and skid resistance values are being recorded. Shown in Photos 5 and 6 are the latest visuals of the test sections. The first section has been In service for two and a half years and the second section for one year.

6.1 First Test Section

The first test section at present is catering to light traffic of 5-10 commercial vehicles per day, which generally increases to about 100 vehicles during winter (October-February). It is estimated that the section has so for carried about 12000 commercial vehicles. The profiles of the section measured at regular intervals are shown in Fig. 2. The transverse profiles indicate that the section has undergone settlement to the extent of 10-20 mm. As only light vibrating equipment was used in construction, the magnitude of settlement

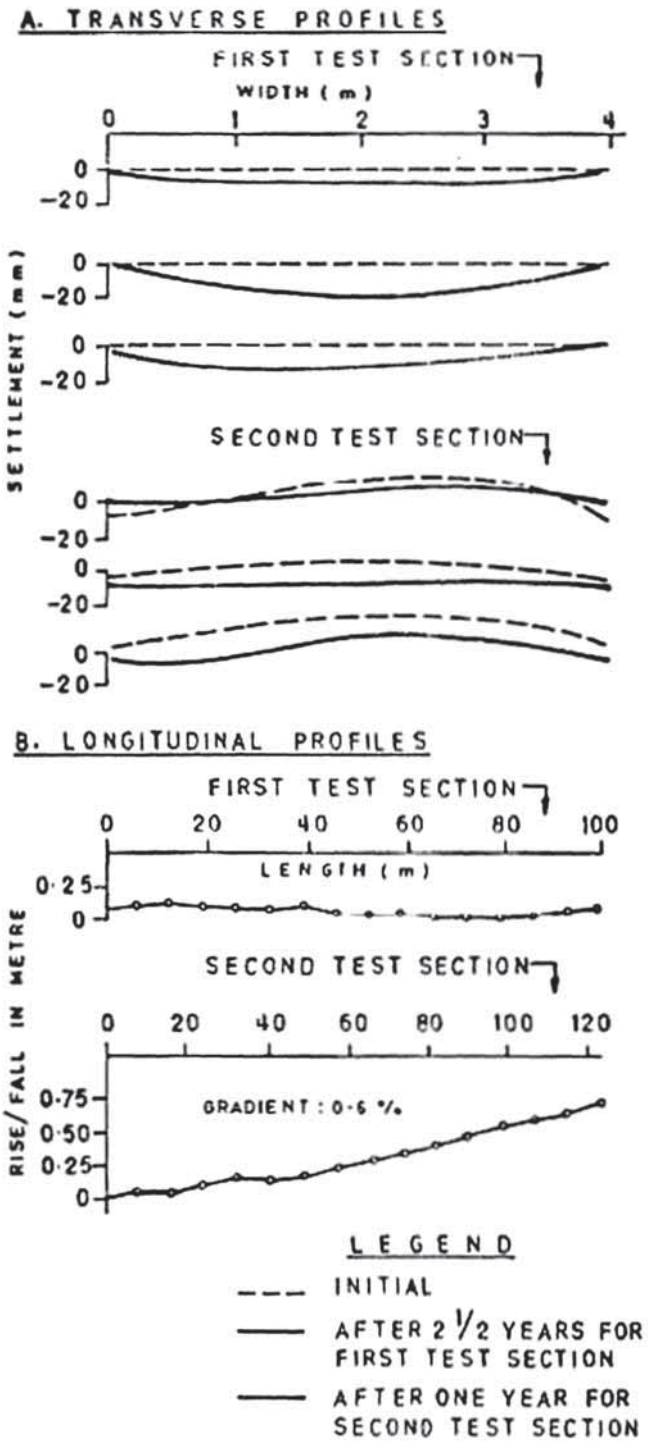


Photo 5: First test section after two and a half years of service.



Photo 6: Second test section after one year of service.

FIG.2 TYPICAL PROFILES



indicated the need for providing higher initial compaction. Due to the comparatively large number of joints per unit area and the average unevenness as above, the riding comfort is not as good as obtainable on a machine-laid bituminous pavemert.

Deflections were monitored near the dowel joints along the wheel path, using conventional Benkelman Beam method. Initial measurements were taken after the passage of about 1000 vehicles, allowing for the bedding-in period of the pavement. The followin ranges of values were obtained :-

i. Maximum deflection : 0.19 to 0.53mm
ii. Rebound deflection : 0.18 to 0.48mm
iii. Residual deflection : 0.04 to 0.07mm

The values indicated the initial flexible behaviour of the pavements structure. During tests conducted recently, the values had dropped considerably, indicating that the block seating had improved. The initial wet skid resistance values were in the range

of 50-60, which have generally remained unchanged. After the passage of about 3000 vehicles, two blocks along the wheel path developed cracks. The cracking is likely to have been due to inadequate subgrade support. The damaged blocks were replaced by new blocks.

6.2 Second Test Section

Traffic on the second test section has been about 15 commercial vehicles per day. During winter the traffic generally increases to about 100 vehicles. The section has so far carried traffic of around 4500 vehicles. Cross profiles measured at regular intervals (Fig. 2) indicated that the pavement has undergone settlement to the extent of 10-15 mm. Unevenness along the wheel path was also observed to be in the same range. The wet skid resistance was in the range of 50-60. About 2 per cent of the blocks along the wheel path had developed structural distress and are being replaced. Investigations showed that the embankment of height in the range of 2-7 m was undergoing further densification under traffic and otherwise. At the of end one year, settlements ranging from 20 mm to 65 mm were observed at the reference pegs constructed at the shoulders. Even though the embankment formation was left for natural densification for about 6 months prior to paving, the settlements observed at the reference pegs indicated that the interior of the embankment was not well compacted and the site, therefore, was rather unfavourable for trying out the block pavement.

6.3 General Observations

The field study indicates that the new pavement system performs quite satisfactorily if it is placed on a suitable, well compacted formation. The riding quality can possibly be further improved with a thin bituminous surfacing.

7. RELATIVE COSTS

In the background of these field trials, comparative costs were worked out for typical conditions in respect of the conventional flexible pavement and this concrete block pavement. These costs were calculated for both initial construction and total road cost, with the inclusion of routine maintenance and periodic renewals. It is seen that, for a lead of 100 km for key materials, the initial cost of construction of precast block pavement is about 25 per cent higher. But, in terms of total road cost, the precast block pavement becomes economical after about 15 years or so. However, when the material lead is 200 km, the precast block pavement costs less initially itself by as much as 25 per cent. As time passes by, it becomes more and more economical.

8. ADVANTAGES AND NEED FOR FURTHER IMPROVEMENT/MODIFICATION

The main advantages of the block pavement system are as follows:-

i. Suitability for factory production under good quality control.
ii. Direct paving on sand without the use of water.
iii. Unlike in-situ construction, the pavement can be opened to traffic immediately after construction.
iv. Effective confinement of sand.
v. Adaptable to weak foundations.
vi. Removal/replacement of blocks possible in case of need.
vii. Low maintenance cost.

The following aspects are being considered for further improvement/modification of the technique:-

i. Use of blocks at the summit/sag of curves is not possible with the present design. Fabrication of special blocks or use of conventional methods can be considered for such locations.
Comparatively large number of joints per unit area affects the riding comfort. This situation can be improved by the use of precision moulds and better quality control during fabrication. Provision of a thin bituminous surfacing can also be considered.
iii. The speed of paving is slow in manual handling and construction, but the process is labour-intensive. Adoption of mechanical handling and paving can sub-stantially improve the speed.

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