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Behavior of Interlocking Concrete Block Pavement over Stone Dust Grouted Subbase

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Abstract: This paper describes structural behavior of interlocking concrete block pavement (ICBP) that is laid over a subbase of grouted single size aggregate with stone dust and confined by plastic cell made from thin polyethylene. Though the experimental study aims at evaluating the performance of interlocking concrete block pavement by static plate load test on a laboratory setup with three different pockets of cell whose sizes are of 150mm x 150mm, 200mm x200mm and 250mm x 250mm with constant thickness of 100mm, but for the present study, plate load test was carried out on ICBP laid on subbase with confinement of 150mm x 150mm only. Studies were carried out on the behavior of ICBP without and with jointing sand. Elastic modulus of each layer has been back-calculated using the computer program KENPAVE. From the test results it is evident that the pavement without jointing sand deflects about 14% more than that with jointing sand. The determined equivalent elastic modulus of the pavement structure for subgrade soils, subbase and concrete block layer without and with jointing sand are 59.58 MPa, 232 MPa, 470 MPa and 2352 MPa respectively.

Keywords: *Concrete Block, ICBP, Concrete Block Pavement, Equivalent Modulus, and Compressibility*.

I. Introduction:

Interlocking Concrete block pavement has been over four decades and is a very cost effective pavement when compared with conventional flexible or rigid pavements (Ryntathiang, 2005; Singh, 2011). However, there is less interest to implement or use the technology in rural roads of India due to lack of knowledge on its suitability and usage for different application. Properly designed, constructed and maintained ICBPs are long lasting, hard wearing and attractive. Presently, the Interlocking Concrete Block Pavement (ICBP) is getting rapid popularity worldwide as an alternative to bituminous or rigid pavement. It is suitable for the areas like airport, bus stand, port, etc. where conventional pavements are less durable due to many constraints. The interlocking concrete block pavement consists of the surface layer made of solid unreinforced concrete block which is well-restraint on all of its four sides, bedding sand, base or subbase layer and the subgrade. Among the components, precast concrete block pavers layer is the major load-spreading component.

Interlocking concrete blocks are laid on screeded bedding sand, which are spaced between each other at 2mm to 4mm apart and are compacted with a few passes of plate compactor. The spaces between the blocks are filled by jointing sand. After the joints are filled up with sand, more passes of plate compactor is carried out to compact and push the sand further down. When this process is completed, more sand is spread over block and completely fill the joint spaces and after this, one or two more passes of the compactor is made till no more sand can be pushed downwards. By carrying out the above-mentioned process, an interlocking mechanism is created. The unique characteristic of concrete block pavement is its interlocking mechanism that is responsible for the behavior similar to the conventional flexible pavement and ICBP behaves as a system of a whole paver unit.

This paper presents a study on the structural behavior of ICBP, laid over a 100mm thick sub-base of single size aggregate grouted with stone dust and confined by the plastic cell of pocket size 150mm x 150mm. The objective of the research was to find the equivalent modulus of elasticity of ICBP without and with jointing sand.

II. Background:

An experiment was conducted in India using static plate load tests in a laboratory scale model made of steel of 775mm x 775mm x 450mm to study the various parameters on the structural behavior of CBP. In this study a 200mm thick crushed rock was used as subbase. From the test, it was concluded that the strength and laying pattern of block had no influence on the deflection of block pavements, and the deflection of the concrete block surface course decreases with an increase in load and number of load repetitions [16]. Muraleedharan et al. (1996) conducted an experiment in a test section measuring 6 m x 3.75 m in the laboratory of Central Road Researchers Institute. Researchers carried out static test using rigid plate and dynamic load test using Falling Weight Deflectometer (FWD) on pavement with 60 mm UNIPAVE block on bound (lean concrete) and unbound (WBM) base courses. From the study, they concluded that for the same applied pressure, the lean concrete base course exhibited a deflection twice that obtained under WBM base course and the resilient modulus of ICBP layer [14]. A static plate load test was also performed on CBP to study the effect of thickness of subbase material constructed with WBM and WMM. From the study, the researchers concluded that the increase in thickness of subbase from 150 mm to 300 mm had reduced the deflection of the CBP, and the WBM has a higher strength as compare to the WMM subbase [21].

To evaluate the CBP, plate load test and accelerated traffic test were carried in the last decade. From this research, it is concluded that the equivalent elastic modulus of concrete block layer increased with the increase in subbase thickness, and modulus varied from 700 MPa to 3000 MPa [23]. A test on laboratory scale model on ICBP inside a tank of 1m x1m x 1m was performed and from this, it was reported that aggregate base course layer had more load spreading ability due to interlocking action of aggregate particle [10].

Research on the use of stone dust, fly ash, coarse sand and river bed material as subbase material was reported by Praveen Kumar et al in 2006. They conducted CBR test, static and cyclic triaxial test on the above mentioned four common locally available material in India and reported that stone dust had shown the maximum value of CBR but least resistant to rutting [19].

III. Material Properties:

Concrete Block: In the present study, concrete block with the shape of I section and of 65mm thick was used. Average compressive strength of the blocks was more than 30 N/mm^2.

Subgrade: Locally available fine sand from the Brahmaputra River which consists mainly of silt and having maximum dry density of 1.99 gm /cc at optimum moisture content of 14 % with specific gravity of 2.02 was used as subgrade material.

Aggregate: Crushed aggregate collected from the crushing plant near to the IIT Guwahati was used as the subbase material. For this study a single size aggregate having nominal size of 13.2mm was used in the study. This nominal size was made to pass wholly on 22.4mm and retain on 11.2mm (MORTH, 2001).

Stone dust: Waste Stone dust is also collected from the same local crusher plant where the aggregate was collected and the sand was used as a grouted material.

Bedding and jointing sand: Locally available Brahmaputra river sand having a maximum size of 9.5 mm and conforming to zone III of IS code was used as bedding sand (BIS, 1970). Same sand passing 1.18mm IS sieve was used as jointing sand.

Plastic cell: To confine the single sized aggregate which will act as a reinforced subbase layer for the interlocking concrete block pavement, plastic cells made from recycled low density polyethylene (LDPE) sheet of 0.26 mm thick was fabricated. Sheets of 100mm in width and approximately 3m long strips were cut manually. Two sheets were joint together and sealed by electric sealing machine at specified and marked locations to join the two together. Subsequently, other sheets were added and joined together at marked locations to make the plastic cell of 150 mm x 150 mm, 200 mm x 200 mm and 250 mm x 250 mm.

IV. Test Setup:

Static plate load tests have been conducted in the test bed which is constructed inside the laboratory. The plan area of the test setup is 2m x 2m, and the depth of the test pit is 1.5m from the floor level. The loading frame comprises of a reaction frame. It has been framed with three rigid I- section beam welded properly and founded suitably in the ground. Load was applied to the pavement structures manually by operating the hydraulic jack of 100kN capacity through the circular plate of 300mm diameter. Before the test is conducted on the different layers of the pavement structure, a pre calibrated proving ring is placed between loading jack and circular plate. Total eight dial gauges (four on each side of the proving ring) having least count of 0.01mm was used to measure the deflection of the subgrade, subbase and surface of the pavement.

Figure 1: Experimental test setup constructed in the laboratory

V. Preparation of Test Section:

Subgrade that was previously placed and compacted in 10 layers of approximately equal thickness at its optimum moisture content was checked for its density before a subbase layer can be placed on it. Load of 10kN was applied to the surface of the subgrade through the hydraulic jack and surface deflection was noted on each side of the plate at the center of the load, 300mm, 600mm and 900mm. These data were later used to determine the modulus of the subgrade.

Before placing the subbase materials on top of the subgrade, plastic cell of height of 100mm and pocket size of 150mm x 150 mm is stretched fully and tied to the wooden frame of width 2m x 2m and height 100 mm. Single size aggregate is subsequently filled into these pockets of each cell. To avoid damage of the plastic cell, initially the pockets were half fill, and afterwards, they are filled fully up to the required thickness. After placing, the aggregate into the pockets of each cell, stone dust mixed with 1% water was spread on the surface of the aggregate and hand broom was used to sweep the wet screenings into the voids of the aggregates and to distribute them evenly to fill the voids completely. The layer is compacted by plate compactor. The sweeping and compaction operation is continued until the aggregates keyed with each other thoroughly and firmly. After the process of compaction on the subbase material is over, plate load test was carried out on the compacted subbase. A load of 30kN was applied through the hydraulic jack and deflection measurements of the surface was noted at the center of the load, 300mm, 600mm and 900mm on each side of the load application. These deflection data was later used to backcalculation of the subbase modulus.

The bedding sand is placed on the thin plastic and spread uniformly throughout the area having loose thickness of 50mm. Concrete blocks are placed manually on the top of the bedding sand. They are laid in stretcher bond pattern. After placing the block pavers, compaction is carried out with plate vibrator for two passes. Plate load test was applied on the block surface layer at a load of 50kN and surface deflection was noted at the center of the load, 300mm, 600mm and 900mm respectively.

After the application of load on the block layer without jointing sand, the same sand that was used as bedding material was made to pass through the IS sieve of 1.18mm and spread on laid blocks. The sand is brushed into the joints and compacted so that the sand can fill the gaps in between the blocks. More jointing sands was spread on the surface layer and compaction was again carried out until the sand refuses to go into the gap between the block.

Results of the test on all of the layers are shown in Table I.

Table I: Deflections on top of each layer

Layer		Dial Gauges reading in mm			
		0	300	600	900
Subgrade		0.47	0.06	0.01	0.01
Subbase		3.455	0.015	0.015	0
Concrete Block	Without Jointing Sand	3.55	0.025	0.0125	0.005
	With Jointing Sand	3.15	0.575	0	0

VI. Analysis of Test Result:

A. Equivalent Elastic Modulus of Subgrade

The elastic modulus of subgrade was calculated from the following formula (Huang, 2004) and it was found that the subgrade modulus was about 60MPa:

$$E = \frac{\pi\left(1 - v^2\right)qa}{2w} \quad (1)$$

Where,

E= modulus of elasticity of Subgrade,
q= average pressure,
a= radius of rigid plate,
v= poison's ratio (=0.40),
w= surface deflection

B. Evaluation of Elastic Modulus of Subbase and Top Layer

The equivalent elastic modulus of the subbase was backcalculated using the 'KENPAVE' an elastic layer computer program developed by Huang (2004). KENPAVE is a multilayer computer program used to analyze flexible as well as rigid pavement. KENLAYER is for flexible pavement and KENSLAB is for rigid pavement. Equivalent modulus of elasticity of subbase and concrete block pavement is calculated by assuming Elastic Modulus of the layers and comparing the deflection with that of obtained from laboratory investigation. Iterative process is continued till the both deflections are equal. The input data required for the program is modulus of elasticity of Subgrade, assumed modulus of layers, thickness of the layers, poisons ratio of the layers.

Figure 2. Experimental model for compressibility of Subbase

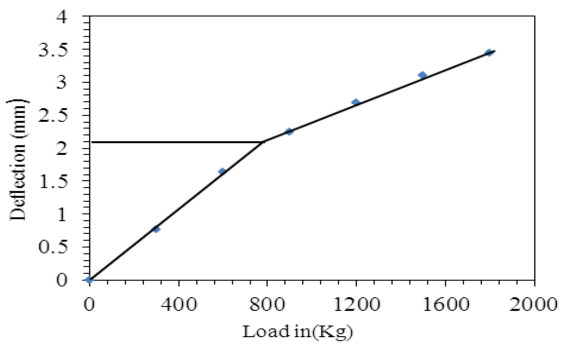

Figure 3. Determination of compressibility value

During the ongoing test on the subbase layer, it was observed that the deflection of subbase is greater than the deflection of subgrade when deflections are compared at the same load, i.e. at 10kN. This observation leads us to think and assumed that there is a compression of the subbase material and that the material had undergone compression before it can actually spread the load to the subgrade layer. To determine the compressibility of the subbase material, a model test was carried out as shown in Figure 2.

With the same dimension of the plastic cells as in the test pit, the aggregate confined on all side and grouted by stone dust and compacted as carried out in the test pit is tested separately and load is applied in an incremental manner of up to 30kN. Figure 3 shows the test results and at the point where there is a change in slope of the line, that point has been taken as the compression value of the layer. This value was deducted from the measured deflection of the subbase layer and the value thus obtained after deduction was taken as the deflection at 0mm and together with the measured deflections at 300mm, 600mm and 900mm respectively, the modulus of the subbase layer was backcalculated by KENLAYER after fixing the modulus of subgrade layer from equation 1. Results of the analysis are shown in Table 2.

By fixing the modulus of the subbase and subgrade layers respectively as input in the KENLAYER program, the modulus of the concrete block layer is varied in the program to match the calculated deflection with the measured deflections on the surface of the block layer without and with jointing sand after corrections on the subbase deflection was made. The corrected deflections as well as equivalent elastic modulus of subbase and concrete block layer are shown in the Table II.

Table II: Equivalent Elastic Modulus of Subbase and Top Layer

Layers	Deflection in mm			Equivalent Elastic Modulus (MPa)
	Observed	Compressibility	Corrected	
Subbase	3.445	2.10	1.345	232
ICBP without jointing sand	3.55	2.10	1.45	470
ICBP with jointing sand	3.15	2.10	1.05	2352

VII. Conclusion:

Based on the study carried out, the following conclusions can be brought out:

a. From the study it was observed that the subbase material undergo compression before it actually take the stresses from the applied load.
b. The use of jointing sand in the space between the blocks helps in distributing the load and reduces the deflection of concrete block pavement by about 14 %.
c. The Equivalent modulus of elasticity of concrete block pavement without jointing sand and with jointing sand are 470 MPa and 2352 MPa respectively.

References:

[1] Bureau of Indian Standards (BIS), (1966). "Determination of Dry Density of Soils, In-Place, by the sand Cone Replacement Method." *IS 2720 - 1966, Part 28*, New Delhi, India.

[2] Bureau of Indian Standards (BIS), (1970). "specification for Coparse and Fine aggregates from Natural Sources for Concrete." *IS:383-1970*, New Delhi, India.

[3] Bureau of Indian Standards (BIS), (1983). "Methods of Test for Soils, Part VIII, Determination of Water Content- Dry Density Relation using Heavy Compaction." *IS 2720-1983*, New Delhi, India.

[4] Central Road Research Institute, "Development of special Purpose Paving Blocks in India." *Second International conference on Concrete Block Paving*, Delft, April 10-12, 1984.

[5] Concrete Block Paving Book 2. (2004). "Design Aspects." 4th edition, *Concrete Manufacturers Association*, 2004.

[6] Huang Y. H (2004). "Pavement Analysis and Design*",2nd edition, Pearson Education, Inc*,2004.

[7] Ishioroshi K., Sekine, S., Hata, M., Suda S., Kagata M., and Utumi, G. (1996). "Review of Function of Jointing Sand, Bedding Course Sand and Base Structure in Concrete Block Pavement." *Proc., 5th Int. Conf. on Concrete Block Paving* , Tel Aviv, Israel, 141 – 149.

[8] Kapur S., Muraleedharan, T. Nanda, P.K. (1996). "Experimenting with Interlocking Concrete Block Pavement in the Himalayas", *The Indian Concrete Journal*, Vol. 70 No. 1, pp. 37-43.

[9] M.P. Dhir, Muraleedharan and P.K. Nanda (1988). "Concrete Block Paving-Full Scale Field Experiment in India, *Proceedings, 4th International conference on CBP*, Rome, Itally, p.429.

[10] Mampearachchi,W.R. and Gunarathna,W.P.H., (2010). "Finite-Element model approach to determine Support Conditions and Effective Layout for Concrete Block Paving." *Journal of Materials in Civil Engineering*, Vol.22 , No. 11.

[11] Ministry of Road Transport & Highway (MORTH), (2001). "Specifications of Road and Bridge Works." Third Revision, Indian Roads Congress, New Delhi, India.

[12] Miura Y., Makiuchi K. and Kureha M., (1992). "An Evaluation of the Performance of Concrete Blocks on Road Pavements under Traffic Loads." *Proc. 4th Int. Conf. on Concrete Block Paving*, Auckland, New Zealand, Part II, 1 – 10

[13] Moghadas.F.,Shadravan M.R., (2010). "A Study on behavior of block pavement using 3D finite element method", *Computational Methods of civil Engineering* 2010, vol.1, No.1 pp.65-71

[14] Muraleedharan, T., Nanda, P. K. (1996), "Laboratory and field study on interlocking concrete block pavement (ICBP) for pecial purpose paving in India." *Pave Israel-96*, 413-422.

[15] Muraleedharan, T. and Sood, V.K. (2003). "Past and Present Efforts for Popularisation of Interlocking Concrete Block Pavement Technology in India" *Proceedings of the 7th international conference on Concrete Block Paving* (Pave Africa 2003), Sun City, South Africa.

[16] Panda, B.C. and Ghosh, A.K.,(2002) "Structural Behavior of Concrete Block Paving. II: Concrete Blocks." *Journal of Transportation Engineering*, Vol.128, No.2, March 1, 2002.

[17] Panda, B.C., Ghosh, A.K., (2001). "Source of Jointing Sand for Concrete Block Pavement". *Journal of Materials in Civil Engineering* . Vol.13, No 3,May/June,2001

[18] Panda,B.C., Ghosh,A.K., (2002) "Structural Behavior of Concrete Block Paving. I: Sand in Bed and Joints." *Journal of Transportation Engineering*, Vol. 128,No 2,March 1, 2002.

[19] Praveen Kumar, Satish Chandra, R.Visha, (2006). "Comparative Study of Different Subbase Materials." Journals of Materials in Civil Engineering, Vol-18,No-4,August1,2006

[20] Rynatathiang .T.L., (2005). "An Investigation on Precast and Cast In-situ Concrete Block Pavement for Low Volume Roads." Ph.D Thesis, Submitted to IIT Kharagpur.

[21] Sharma, S.,Ryntathiang, T.L., Mazumdar,M. and Pandey B.B., (2004). "Structural Behaviour of Concrete Block Pavement on Water Bound Macadam and Wet Mix Macadam Subbase." *Seminar on Design, Construction and Maintenance of Cement Concrete Pavement s*, October, 2004, Indian Road Congress, New Delhi.

[22] Singh Y.A.K., (2011). "A Study on Plastic Cell Filled Concrete Block Pavement for Low Volume Roads", *Ph.D Thesis*, Submitted to IIT Guwahati.

[23] Teiborlang Lyngdoh Ryntathiang, M. Mazumdar and B.B. Pandey, "Concrete Block Pavement For Low Volume Roads" Proceedings, on 8th International Conference on Concrete Block Paving, November 6-8, 2006 San Francisco, California USA, Page 359-373, (November 2006).