Load Transfer Efficiency Concrete Block Pavements For Low Volume Roads

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Abstract- *Concrete Block Pavements (CBP) are precast concrete blocks of varying shapes and sizes arranged in a specific pattern over a variety of sub bases and interlocked with graded bedding and jointing sand. The wheel loads on concrete blocks are distributed due to the interlocking effects between bedding and jointing sand with concrete blocks. Concrete block size and shape, joint gap and joint filling sand size, laying pattern will affect the Interlocking effects. These interlocking effects are quantitatively expressed by Load Transfer Efficiency (LTE) which is the deflection ratio between loaded block to adjacent unloaded block. In the present study, laying patterns (stretcher and basket weave), concrete mixes with fly ash at 20% by weight of cement, steel fiber of 0.5% per cubic meter of concrete and combination of fly ash and steel fiber were used. The Load Transfer Efficiency was calculated based on the tests conducted in the field considering all the variables mentioned above. The test section consisted of granular sub base over the subgrade, the base layer is of wet mix macadam and surface course is the concrete block of different sizes with 100mm thick over the 20 mm thick bedding sand size of 4.75 mm and varying sizes of joint filling sand in 5 mm joints. It was concluded from the study that the Honey style block shape has more restraint for Horizontal creep than square and rectangular shape block. It was also noticed that the deflection observed in Honey style block is less compared to rectangular and square shape. Also, it was noted that with the change in block thickness from 100mm, 80mm, 60mm in case of all the three shapes there is a significant reduction in the elastic deflection of pavement blocks as the load transfer will be higher for the thicker blocks because of the higher frictional area. The combination of steel fiber and fly ash in concrete blocks showed an increase in the load transfer efficiency.*

Keywords- Shape, Thickness, Concrete block Pavement, Load Transfer Efficiency, Laying Pattern, Steel Fiber, Fly ash

I. INTRODUCTION

Low volume road concrete block pavements (CBP) are formed from individual solid blocks that placed closely next to one another to form a pavement surface. The Concrete block pavement consists of small paving units (pavers) bedded and jointed in sand, between edge restraints rather than paving continuously as in the case of bituminous layer or concrete slab. The substructure beneath the bedding sand is similar to that of a conventional flexible pavement. The CBP usually consists of surface, base course and subgrade. Subbase or an improved sub grade may be required on low strength soils. The layers are shown in Figure below

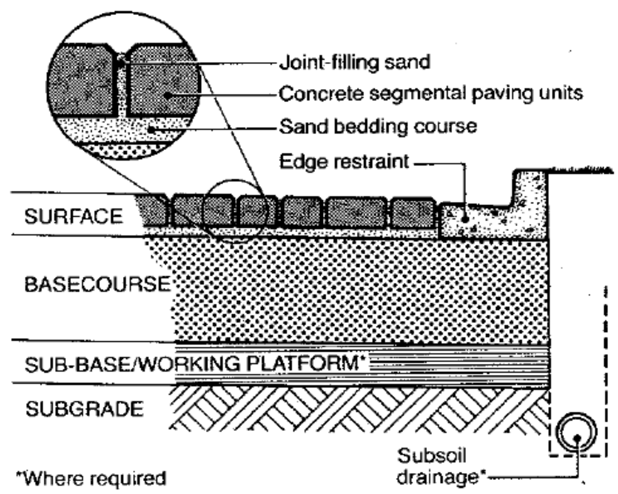


Figure 1. Low volume road Concrete Block pavement Structure

The surface layer comprises of small concrete block units, sand bedding course and edge restraints. The Joints between block units are completely filled with fine sand. The base course consists of one or more layers either Water Bound Macadam (WBM) or cement bound rock or gravel. With low strength subgrade soils, subbase or stabilized subgrade may be required to provide a stable platform for construction of base and surface layers. The subgrade is the prepared insitu soil or fills on which pavement is constructed. Concrete Block Pavement (CBP) is manufactured from semi-dry concrete mixes. Vibration and pressure is applied in the manufacturing process. By this process a dense and strong blocks can be achieved to form strong and durable paving surface. Generally, top layer in pavements is mostly continuous layer made from a bound material either bitumen or concrete. The design of these top layers is based on enough protection to the unbound sublayers in pavement structure and subgrade. To protect them, good fatigue life of top layers is to be ensured. If the top layer fails, i.e. show cracking, the protection they offer to underlying layers decrease. Due to this the complete pavement structure may fail before its design life. In case of CBPs, they completely 'crack', as they have many discontinuous edges in all directions. The design of CBP cannot be designed by determination of fatigue life. The design of concrete block requires a totally different approach than the design of rigid or flexible pavements. Load on the block pavement is transferred to bottom layers by the combination of interlocking effects, bedding sand, joint sand and edge restraints. The load spreading capability to larger area depends on interlocking between the individual blocks with jointing sand of suitable gradation to provide the up resistance against the applied wheel load. Different parameters may influence the interlocking between the block units. Factors that affect the interlock are block size, block shape, block thickness, joint width, laying pattern and edge restraint. The interlocking effect can be quantified in terms of the load transfer efficiency and it is the ratio of deflection at the edge on unloaded black to loaded block.

II. OBJECTIVES OF THE STUDY

The broad objective of the present work is to evaluate the Load Transfer Efficiency (LTE) of concrete block pavement for three different shape such as Rectangular, hexagonal, and square shape similarly for each shape three different thickness(100, 80, 60mm) block laying patterns, interlocking length and type of material used in concrete block manufacturing. The work also aims at evaluating the optimum properties for different layers i.e., subgrade, granular subbase and water mix macadam as base course in CBP system and the effect of different alternative material like steel fiber and fly ash in concrete block pavements.

III. BOND ASPECTS

Now days, much of the road pavement are using the concrete blocks paving methods. However, there still need improvement on the concrete block low volume road pavement because of some failure where are occur. On the actual road construction for an example, when the car starts to accelerate at the junction of the road, the pavement d received the vehicle load of pull out force. If sand bedding is not compacted well, the road pavement is easily going to failure. So, the bonding between the blocks and sand bedding are important for interlocking block pavement. The following are the parameters of the study.

IV. PRELIMINARY LABORATORY INVESTIGATIONS

In the present study,. The basic concrete mix proportioning was done as per ACI method of mix design. The cement, sand and coarse aggregate are in the ratio of 1:1.2:1.8 while the water-cement was 0.5. Flyash was used as a replacement for cement in the manufacture of the Concrete Block Pavements (CBP), while steel fiber of the order of 0.5% by volume was used to improve the performance. An optimum dosage of 20% of flyash was chosen from preliminary studies.. Four patterns of concrete block pavements for different shapes and thickness were prepared. One with rectangular shape of 100 x 100 x 200 mm, arranging them to make two patterns namely basket weave and stretcher bond. For square shape of(150x150x100 mm) arranging them two patterns header and stretcher bond similarly for hexagonal shape 100mm thickness and each side 100mm arranging them one pattern namely honey style bond. In each case sets of 8 blocks were used for each pattern and in each shape thickness respectively (100, 80, 60 mm) changed for test section. Five sizes of joint filling sand combination were used.

Figure 2. Wet material mixing(C)

Figure 3. Internal Vibratore

Photo .1: View of Mixing of Cement Concrete for Block Casting and Preparation

V. CONSTRUCTION OF TEST SECTION

The concrete block test section maybe of any for three different shapes such as (rectangular, square, hexagonal) and for each shape three different thickness respectively (100, 80, 60mm) also 20 mm bedding sand, 300 mm WMM base and 400 mm GSB layer.

1) Subgrade Preparation

Test pit of 420x420 mm with depth of 820 mm was excavated in one of the sites in NIT, Warangal. The surface is compacted such that the density is not less than that of surrounding undisturbed soil. The surface is leveled to carry out the Loadman deflection study. The deflection value obtained from the Loadman is 1.2 mm and the corresponding elastic modulus is 36 MPa. Photos 4.1 and 4.2 show the test pit and the deflection studies with Load man respectively.

Figure 4. A View of Pit for Construction of Test Section

Figure 5. Progress of Deflection Study

2) Subbase Preparation

The subbase layer is 400 mm thick and it was compacted in 2 layers. Each layer was compacted using hand tamp rods till it reached a Proctor density of 93 The average elastic modulus for the subgrade and subbase was 52 MPa

3) Base Preparation

The base layer is wet mix macadam of 300 mm and it was laid in 2 layers. The optimum amount of water i.e. 7.36% was added by weight of the crusher-run aggregates and fines test mix and manual mixing was done by shovel and spade. Immediately after mixing, the WMM mix was spread evenly upon the prepared GSB layer. Care was taken to avoid the segregation of fine and larger particles which may result in pockets of loose fine materials. The surface of the aggregates was checked with templates and all high and low spots were avoided by adding or removing the aggregate as may be required. Compaction was done with a tamping foot till the layer reaches 98% of maximum dry density which was estimated in lab as 2890 kg/m3. Photo 4.3 shows the compaction of WMM with tamping rod. After the compaction, the layer was allowed to dry for 24 hours. Deflections were taken with Loadman and average deflection on the base layer is 0.7 mm which results a elastic modulus of 77 MPa.

a) Bedding Sand

Bedding sand of 20 mm thick was spread on the prepared base layer. The grain size of bedding sand is passing 4.75 mm and retaining on 2.36 mm (Hodkinson, 1982). It was

b) Joint Filling Sand

Five size combination of joint filling sand they are 1.8 ,0.6 , 0.3, 0.15 and 0.075mm were used in all concrete block shape types and laying patterns which are, stretcher bond, Square header, square stretcher and hexagonal honey style bond patterns

Table 1. Parameters considered for Load Transfer Experiment

Variable Type	**No of Variables**
Type of concrete block shape	3
Laying pattern and Block shape(stretcher bond ,basket weave bond, Hexagonal, square stretcher, and square header bond)	5
Type of thickness for each shape(100, 80, 60mm)	3
Total combinations to be tested	***15***

V. EXPERIMENTAL SETUP

The concrete block test section was loaded with a passenger car (Model: Ford Figo). One side of the front and rear axle was loaded on one block to measure the load transfer efficiency. Half of the vehicle load was transferred on to the test section by a jack. The load applied on the pavement was measured with a proving ring of capacity 10,000 kg. While measuring the vehicle load, the vehicle was kept on a leveled surface. The vehicle load applied at centre of a block is 1426 kg. Below the jack, wooden block (80x80 mm) was kept on the centre of the block to apply the uniform load over the block and deflections were measured on Short and Long edges on either side of the joint. Four dial gauges were used to take deflections at joints on Short and Long edges of the block. The least count of the dial gauges was 0.01 mm.

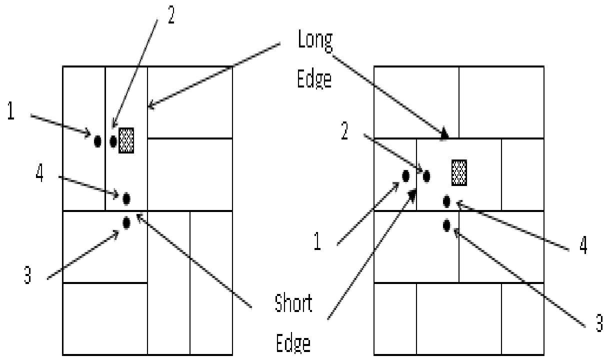


Figure 6. (a) Basket Weave (b) Stretcher Bond Locations of Dial Gauges for Deflection Measurement

Figure 7. Deflection Measurement in Basket Weave and honey style Pattern

VI. LOAD TRANSFER EFFICIENCY

It was mentioned in literature that the load applied on to a concrete block is distributed to the surrounding block and to the base by combination of interlocking effects, bedding sand, jointing sand and edge restraints. Figure below explains the deflection (Δz) due to a compressive load applied on a concrete block and its distribution to the surrounding block through volumetric expansion of jointing sand i.e. dilation.

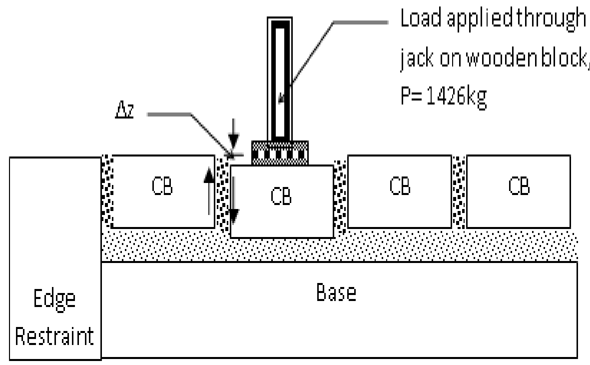


Figure 8. Load Transfer from a Concrete Block

As mentioned earlier, laying pattern, materials used in concrete block and size of the joint filling sand will influence the performance of the block pavement. Table below shows the in-situ deflection values measured for test section with the above combinations.

Table 2. Deflection Values for Different shapes and thickness

Laying Pattern	**Block Type (material used)**	**Direction of Deflection Measurement**	**Deflection Values**	
			Joint width 5mm	**Load transfer efficiency %**
Rectangular Basket Weave	Steel fibre + Flyash 100mm	Short Edge	L*3-0.40mm	80
			L*4-0.50mm	
		Long Edge	L*1-0.43mm	86
			L*2-0.5mm	
	Steel fibre +Flyah 80mm	Short Edge	L*3-0.33mm	70
			L*4-0.47mm	
		Long Edge	L*1-0.40mm	75
			L*2-0.53mm	
	Steel fibre +	Short Edge	L*3-0.15mm	60
			L*4-	

	Flyash 60mm		0.25mm	
		Long Edge	L*1 – 0.16mm L*2- 0.25mm	64
Rectangular Stretcher Bond	Steel fibre + Flyash 100mm	Short Edge	L*1- 0.35mm L*2- 0.47mm	74
		Long Edge	L*3- 0.39mm L*4- 0.50mm	78
	Steel Fibre +Fly ash 80mm	Short Edge	L*1- 0.33mm L*2- 0.47mm	70
		Long Edge	L*3- 0.40mm L*4- 0.53mm	75
	Steel fibre + Flyash 60mm	Short Edge	L*1- 0.15mm L*2- 0.25mm	60
		Long Edge	L*3- 0.16mm L*4- 0.25mm	64

Note: L* =Dial location for deflection measurement

Table 3. Deflection Values for Different shapes and thickness

Laying Pattern	**Block Type (material used) and thickness**	**Direction of Deflection Measurement**	**Deflection Values**	
			Joint width 5mm	**Load transfer efficiency %**
Square shape header bond	Steel fibre + Flyash 100mm	square Edge	L*3- 0.39mm L*4- 0.50mm	78
		square Edge	L*1- 0.40mm L*2- 0.53mm	75
	Steel fibre+Flyash 80mm	square Edge	L*3- 0.33mm L*4- 0.47mm	70
		square Edge	L*1- 0.25mm L*2- 0.37mm	67
	Steel fibre + Flyash 60mm	square Edge	L*3- 0.13mm L*4- 0.21mm	62
		square Edge	L*1 – 0.32mm L*2- 0.42mm	59
Square shape stretcher bond	Steel fibre + Flyash 100mm	square Edge	L*3- 0.40mm L*4- 0.53mm	75
		square Edge	L*1- 0.25mm L*2- 0.36mm	69
	Steel fibre+Flyash 80mm	square Edge	L*3- 0.26mm L*4- 0.40mm	65
		square Edge	L*1- 0.15mm L*2- 0.25mm	60
	Steel fibre + Flyash 60mm	square Edge	L*3- 0.22mm L*4- 0.40mm	55
		square Edge	L*1 – 0.22mm L*2- 0.30mm	56
Honey style shape	Steel fibre + Flyash 100mm	honey style Edge	L*1- 0.85mm L*2- 0.90mm	94
		honey style Edge	L*3- 0.80mm L*4-	88

			0.90mm	
	Steel fibre + Flyash 80mm	Honey style Edge	L*1-0.40mm	80
			L*2-0.50mm	
		Honey style Edge	L*3-0.40mm	75
			L*4-0.53mm	
	Steel fibre+Flyash 60mm	Honey style Edge	L*1-0.33mm	70
			L*2-0.47mm	
		Honey style Edge	L*3-0.26mm	65
			L*4-0.40mm	

Note: L* =Dial location for deflection measurement

The interlocking effects can be quantitatively expressed by Load Transfer Efficiency (ηlt) and the Figure 1.5 show the measurement of deflection in CBP .

The Load Transfer Efficiency (ηlt) is expressed as follows.
$\eta lt = \Delta 1/\Delta 2 \times 100$

Where, Δ2 is the deflection at the edge of loaded slab and Δ1 is the deflection at the edge of unloaded slab.

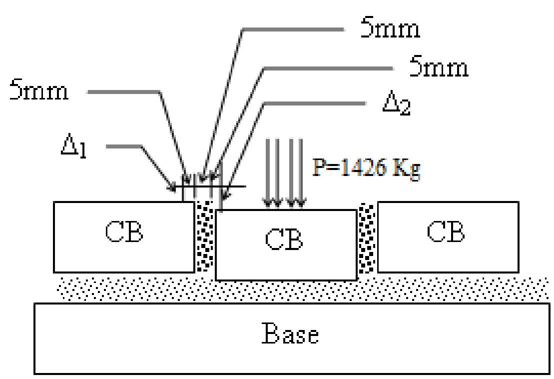
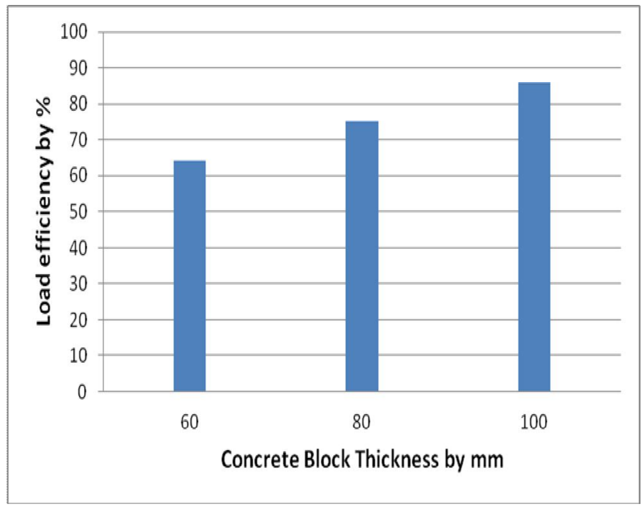


Figure 9. Measurement of Deflection in CBP for Load Transfer Efficiency

It can be sited that in general for all the steel+fly ash combinations of material concrete blocks, the LTE is Honey style higher as compared to basket weave and stretcher bond. Similarly, in all the cases the value of rectangular shape LTE is higher in long edge as compared to shorter edge. The reason can be attributed to the larger contact length of the friction on long edge, which is true in both the patterns.

Further, it can be noted that in all the cases, the combination of steel fibre + flyash resulted in a better LTE as compared to other materials used. The reason for this can be attributed to the fact that the LTE of concrete block depends on the compressive strength of the concrete block and efficiency of transferring load with crack propagation. This was very much true in case of fibre based specimens. The compressive strength as noted earlier was also higher in this combination. It was easily noted from the plots that the fly ash + steel fibre was having higher values.



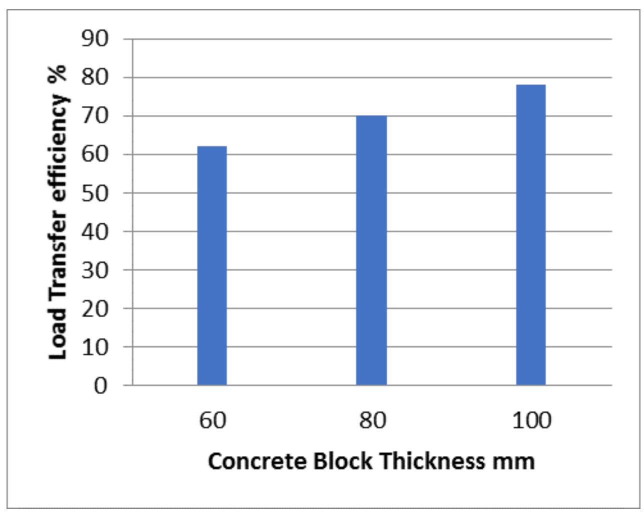
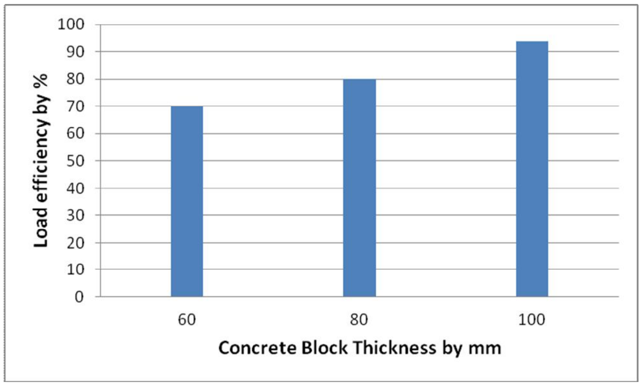


Figure 10. Load transfer efficiency of rectangular shape basket weave and Square shape header concrete blocks



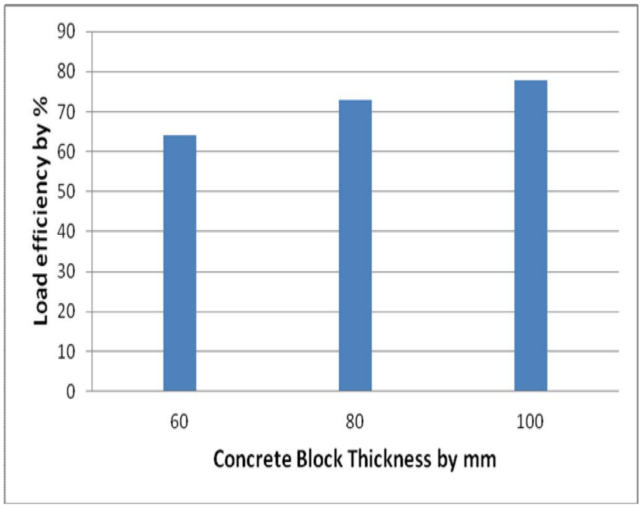


Figure 11. Load transfer efficiency of hexagonal and Rectangular stretcher Bond in concrete blocks.

VII. CONCLUSION

Load Transfer Efficiency for CBP system is determined in field by constructing a test pit of dimensions 420x420 mm and 820 mm depth. Granular subbase of thickness 400 mm in 2-layers was constructed on the prepared subgarde having elastic modulus of 36 MPa. WMM of thickness 300 mm was constructed in 2-layers and compacted to 98% of laboratory dry density. 20 mm thick bedding sand was placed on the base layer. Concrete block of 200x100x100 mm were laid in basket weave and stretcher bond patterns.

It was concluded for the study that the Honey style block shape show the high load transfer efficiency more restraint of Horizontal creep than Square, Rectangular shape block. Has gear (six-dents) the difference in deflection observed between Honey style, Rectangular and Square shape the change in block thickness from 100mm, 80mm, 60mm significantly reduces the elastic deflection of pavement thicker blocks providing a higher frictional area the load transfer will be higher for the thicker blocks the response of the pavement is highly influenced by block thickness.

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