# An Overview of Interlocking Concrete Pavements

**Arpita Verma[1] Sunil Kumar[2] Ankit Sethi[3]**
[1,2,3]Department of Civil Engineering
[1,2,3]WCTM, Farukhnagar, Gurugram, Haryana, India

*Abstract*— In many parts of the world Interlocking Concrete Pavement (ICP) is rapidly gaining popularity for roads, airports and industrial pavements. The history of ICP starts in 19th Century when paving stones were used in European countries for roads construction serving as footpaths and tracks for steel-wheeled vehicles. The use of small stone elements to create a hard surface for roads or pavements is an ancient tradition dating back to Greek and Roman times. The use of ICP occurred in post war Holland in 1940‘s as a replacement for clay brick streets. ICP was introduced in North America in the mid-1970s and have been successfully used in many pavement applications. There are a wide range of ICP applications including city streets, driveways, crosswalks, sidewalks, parking areas, ports, container terminals, and airports.

***Keywords:*** Bedding sand, Jointing sand, asphalt or concrete paverment, base, sub-base, sub-grade, edge restraint, laying patterns

## I. Introduction

ICP was introduced in North America in the mid-1970s and have been successfully used in many pavement applications. Currently, there are approximately 60 million square meters and 300 million square meters of concrete pavers are produced annually in North America and Europe respectively. There are a wide range of ICP applications including city streets, driveways, crosswalks, sidewalks, parking areas, ports, container terminals, and airports.

ICP have many advantages, like resistance to freeze-thaw and deicing salts, high abrasion and skid resistance, there is no need for heavy construction equipment, easy maintenance and low maintenance cost, no thermal expansion and contraction of concrete pavers, instant opening to traffic, accommodates higher elastic deflections without failure, access to utilities, protection from fuel and oil spillage, and environmentally friendly technology.

## II. Research Scopes and Objectives

The Interlocking Concrete Pavers Have Provided Many Benefits, There Is Some Evidence Of Early Failures With Respect To Use In Crosswalks. There Have Been Varying Failure Modes Noticed And There Needs To Be A Better Understanding Of The Various Design Aspects Of Using ICP In Crosswalks, Low Traffic Roads Etc.

The main objectives of the project are:

- To explore the alternative material like aluminum sheet to reduce the differential settlement for better riding quality of interlocking pavement
- To explore the possibility of reducing construction cost and construction time
- To explore the increase of sub grade CBR by providing aluminum sheet

## III. Methodology

For the purpose of assessing structural performance of interlocking concrete block pavement granular sub base will be replaced with aluminum sheets.

- To evaluate the thickness of sub-base, CBR test will be conducted according to IS: 2720 (16):1987. For this purpose aluminum sheet of varying thickness from 1mm to 10 mm is to be placed on top of sandy soil sub grade.
- Before CBR test other tests will be conducted on soil specimen. They are:
  - Dry and wet sieve analysis as per IS 2720 (4) for soil classifications.
  - Procter test as per IS 2720 (6) to find maximum dry density at optimum moisture content.
- At last % change in CBR will be noted for the specimen with and without aluminum sheet

## IV. Literature Review

Interlocking Concrete Pavement (ICP) varies from other forms of pavement that is the wearing surface is made of small paving units bedded and jointed in sand rather than continuous paving. Beneath the bedding sand, the substructure is similar to that of a conventional flexible pavement. The material of concrete block pavement is rigid, but the construction is flexible pavement (Hasanan, 2005).

In ICP, major load-spreading components are blocks which is comprised of concrete blocks bedded and jointed in sand. Interlock has been defined as the inability of an individual paver to move independently of its neighbours and has been categorized as having three components: horizontal, rotational, vertical. Interlock is of major importance for the prevention of movement of pavers horizontally when trafficked (Knapton, 1979).

### *A. ICP Components*

An ICP is a flexible pavement in which the surfacing consists of concrete pavers laid on a thin layer of sand referred to as the laying course or bedding sand (Beauty, 1992). The base layer constructed using untreated aggregate, asphalt treated base or cement treated base. If either an asphalt base or cement treated base is used a granular subbase layer maybe placed underneath the treated base layer.

### *B. Interlocking Concrete Paver (ICP)*

Interlocking concrete paver is a unique material, exhibiting important differences to other small element paving such as stone and clay, as well as to form-less materials such as asphalt and in-situ concrete. It provides a hard surface which looks good, comfortable to walk on, extremely durable and maintenance is easy. It adds richness, complexity and human scale to setting (Bin, 2006). The pavers are designed to be placed together with paver to paver joints filled to develop frictional interlock.

The concrete paving blocks used generally 200 mm to 250 mm long and 100 mm to 112 mm wide. The thickness of the blocks used from 60 mm to 100 mm, depending on the intensity of traffic. The paving blocks are typically installed on a sand bed 20 mm to 40 mm thick, separated by sand joints of 2 mm to 4 mm (Koon, 2000).

The pavers may be rectangular or one of more than two hundred proprietary shapes. There are three categories of paver shape (Morrish, 1980). Category A comprises dentate blocks which key into each other on all four faces. Category B comprises dentated blocks which key into one another on two faces only and category C comprises non-dentated blocks which do not key together geometrically.

The rectangular concrete pavers consist of spacer bars to secure a space between adjoining paver units which protrude not more than 2mm from the sides of the pavers. The spacers ensure a minimum joint width and allows joint sand to enter and reduces the edge spalling. The spacer bars are suggested to extend the full height of the paver that is from bottom to the top (ICPI, 2004).

### C. Laying Patterns

The laying pattern for ICP chosen to support traffic loads should be resistant to horizontal creep. Many of the paver shapes can be installed in a variety of patterns. The most commonly used patterns are herringbone, stretcher, basket-weave and parquet bonds. Accelerated trafficking tests have been used to compare the performance of these patterns. In general, the best level of performance is found in pavements in laying herringbone bond, while the greatest deformations are associated with stretcher bond pattern (Shackel, 1980). The Herringbone pattern can have three orientations relative to the direction of traffic. It should be laid at 45$^{o}$ to resist the traffic shear stresses. Sailor and soldier courses can be placed against edge restraint to prevent the surface from the formation of shear plane.

## V. Interlocking Concrete Pavement Design

Several methods for designing ICP for roads and streets are available now. Many methods are the extensions of flexible pavement design methods because the load distribution and failure modes of ICP and flexible pavement are very similar. There are a number of limitations including inadequate characterization of the subgrade soil and paving materials, lack of pavement performance prediction, and inability to specify desired pavement failure and reliability level (Rada, 1990). All need to consider the subgrade soil, paving materials, environment, and anticipated traffic.

Shackel (1980) has summarised the diffrent design procedures developed around the world. These methods can be divided into four categories as follows:

### A. Design on the basis of Experience

In this method, the thickness of pavement is selected on the basis of road construction experience. The design catalogues are developed according to subgrade conditions or traffic loads.

### B. Ad-Hoc Modification of Conventional design Methods

In this method, concrete pavers are substituted part of flexible pavement. The pavers have been reported as being equivalent to 2.1 and 2.9 times their thickness of crushed stones and to be between 1.1 and 1.5 times more efficient that asphalt concrete (Shackel, 1978). Some design curves were developed by using this method and adopted by the Asphalt Institute and Corps of Engineers in design procedures.

### C. Mechanistic Methods of Design

This method was developed on the basis of observed pavement response of actual interlocking concrete pavement under traffic. The test was conducted at the New South Wales University in 1978 and some design curves were developed (Shackel, 1980). The major drawback of these curves was that they had not been evaluated at subgrade CBR values less than 16 (Sharp, 1986).

There are a number of limitations associated with the above mentioned design procedures. The design methodology lacked the pavement performance prediction and materials and subgrade characterisation. Rada (1990) developed a new methodology to overcome these disadvantages. The AASHTO flexible pavement design methodology (AASHTO, 1986) was used as the fundamental to develope this procedure. The AASHTO method was modified for the design of ICP. In particular, a strength characterisation for concrete pavers was developed and alternate procedures for characterising the environment, traffic, subgrade, and the materials were also developed.

The design methodology developed is based on the evaluation of four primary factors and their interactive effects by Rada (1990). They are environment, traffic, subgrade soils and materials. The evaluation will determine the final pavement thickness and material.

## VI. Parameters Influencing ICP Performance

There are many factors which affect the performance of interlocking concrete pavement. The principal factors which contribute the performance of the pavements under traffic are traffic, subgrade, base and subbase, bedding sand, jointing sand, edge restraint, paver shape, paver thickness, laying pattern, drainage, compaction and strength.
Effect on Comp. Strength by Different Materials Used For Manufacturing Pavers:

### A. Use of Nylon Fiber and Rice Rusk Ash

Pre-cast cement concrete paver blocks is solid and unreinforced these material is a versatile, aesthetically attractive, functional, cost effective; if correctly manufactured and laid it requires little maintenance. Paver blocks can be used for various traffic categories that is Non-traffic, Light-traffic, Medium-traffic, Heavy-traffic and Very heavy traffic. In present study done by E.A.Reddy, Vishal Gupta And Deepak Garg (2015), work paver blocks of M-35 grade of 60mm thickness for light traffic with varying percentage of nylon fiber (0.1%, 0.2%, 0.3%, 0.4% & 0.5%) is used to improve the compressive strength is casted. After finding optimum percentage of nylon fiber, the same is used as constant and Rice Husk Ash (RHA) in varying percentage (10%, 20% & 30%) is added (replacement of cement) to check the changes in compressive strength of paver block. It has been found that using Nylon Fiber increases the compressive strength up to 18.86% when we use Nylon fiber upto 0.3%, as compared to conventional mixture; and Nylon

Fiber makes the blocks more opaque as compare to other paver blocks and The optimum dose of 20 % of Rice Husk Ash (RHA) gives maximum strength of paver block.

### *B. Foundry Sand:*

Foundries for the industry of metal-casting generate biproducts such as used foundry sand. Applications of foundry sand, that is technically sound, and environmentally safe for sustainable development. In the study of D.N Patel And J.R. Pitroda (2014), partially replacement of Cement (PPC 53 grade cement) in paver block by using foundry sand for determining the change in the compressive strength and cost of paver block. Partial replacement of cement (PPC 53 grade cement) in bottom layer in various percentage such as 10%, 20%, 30%, 40% and 50%. The compressive strength, flexural strength has been determined at the end of 7, 14 and 28 days and water absorption test determined at 28 days.

### *C. Use of Broken Paver and Kadapa Stone Etc.*

In this M. C. Nataraja and Lelin Das study various properties such as compressive strength, split tensile strength, bending strength and water absorption of paver blocks consisting of crushed granite, unconventional materials like kadapa and broken paver for diffrent percentage replacements of coarse aggregate are studied as per IS 15658:2006.

Broken paver aggregate is not suitable in making paver blocks because absorption is more than 7%. However, 50% replacement of paver aggregate with natural aggregate may be used because the absorption is very close to the permissible limits.

### *D. Use of Natural Fiber*

Study of G. Navya and J.V. Rao (2014) experimental investigation the compressive strength, water absorption and flexural strength of paver blocks were determined by adding Coconut fibers in the top 20mm thickness. Coconut fibers were added in proportions of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in concrete's volume. The compressive strength, flexural strength and water absorption of paver blocks were determined at the end of 7 and 28 days. Test results shows that by 0.3% addition of coconut fiber paver block attains maximum compressive strength. Test results shows that addition of coconut fiber gradually increases flexural strengths and water absorption at 7 and 28 days. In this investigation at 0.3% of coconut fiber content effect of top layer thickness on compressive strength and flexural strength is also determined. Results show that inclusion of fibers even up to 50% of top layer thickness compressive and flexural strengths are increasing.

### *E. Use of Polyester Fiber*

Study of G. Navya and J.V. Rao (2014) investigation the compressive strength, water absorption and flexure strength of paver blocks were determined by adding Polyester fibers in the top 20mm thickness. Polyester fibers were added in proportions of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% in volume of concrete. The compressive strength, flexural strength and water absorption of paver blocks were determined at the end of 7 and 28 days. Test results shows that addition of polyester fiber by 0.4% in paver block, it attains maximum compressive, flexural strengths and minimum water absorption at 7 and 28 days. In this investigation polyester fiber content of 0.4% the effect of top layer thickness on compressive strength and flexural strength is also determined. Results indicate that inclusion of fibers even up to 50% of top layer thickness compressive and flexural strengths are increasing.

## VII. EXPERIMENTAL DATA

### *A. Sieve size analysis of sub grade soil*

| Sieve size (mm) | Wt. retain (gm) | % wt. retain | Cum. Wt. retain | % finer |
|---|---|---|---|---|
| 4.75 | 23.8 | 1.19 | 1.19 | 98.81 |
| 2.36 | 96.2 | 4.81 | 6 | 94 |
| 1.18 | 198.2 | 9.91 | 15.91 | 84.09 |
| .600 | 204.6 | 10.23 | 26.14 | 73.86 |
| .300 | 857.5 | 42.875 | 69.015 | 30.985 |
| .150 | 322.4 | 16.12 | 85.135 | 14.865 |
| .075 | 208 | 10.4 | 95.535 | 4.465 |
| Pan | 89.3 | 4.465 | 100 | 0 |

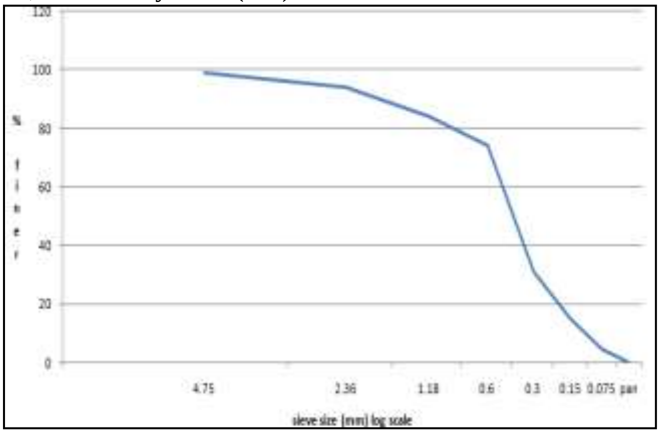
Table 1: dry sieve analysis

$D_{10} = 0.115$, $D_{60} = 0.503$, $D_{30} = 0.300$

$C_u = 4.37$

$C_c = 1.56$ and from wet sieve analysis % of fine particle less than 0.075mm is 20%

So, Soil Is Silty Sand (SM)



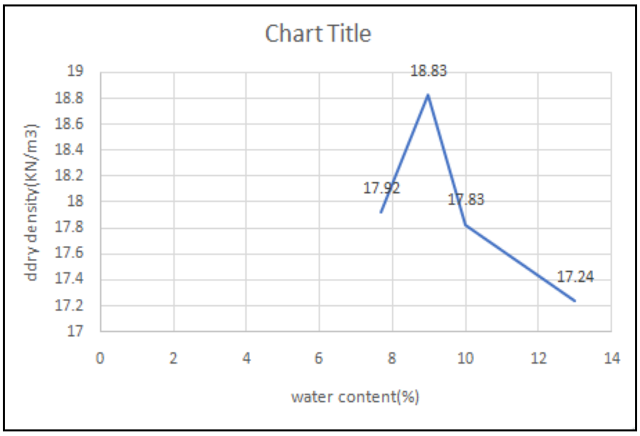

Graph 1: % finer vs sieve size in mm (log scale)

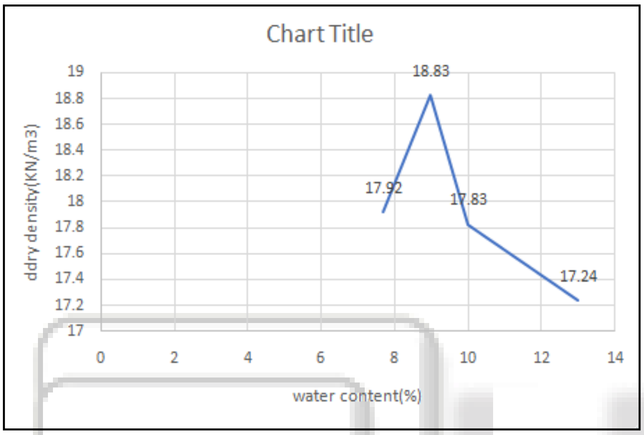
### *B. Proctor test on soil:*

| Wt of mould (kg) | Wt of mould + soil (kg) | Bulk density (kn /m3) | Wt of crucible (gm) | Wt of cr +wt of wet soil (gm) | Wt of cr.+ wt of dry soil (gm) | Water content (%) | Dry density ( kn/m3) |
|---|---|---|---|---|---|---|---|
| 4 | 5.85 | 19.308 | 31.4 | 59.4 | 57.4 | 7.7 | 17.92 |
| 4 | 5.975 | 20.52 | 29.4 | 53.6 | 49.6 | 9 | 18.83 |
| 4 | 5.9 | 19.74 | 30 | 68.3 | 64.6 | 10 | 17.83 |
| 4 | 5.875 | 19.48 | 24.8 | 74.1 | 67 | 13 | 17.24 |

Table 2: proctor test readings

OMC = 9% and MDD= 18.83%




Graph 2: dry density vs water content

## VIII. Conclusion

In this work, suitability of brick kiln dust concrete paving blocks had been evaluated. In this research work, cement was partially replaced by brick kiln dust waste at varied replacement level ranging (0%, 5%, 10%, 15%, 20% and 25%). This systematic study for brick kiln dust concrete had been carried out for w/c ratio 0.40. test for fresh concrete and compressive strength, absorption test have been performed for hardened concrete paving block sample.

Utilization of brick kiln dust waste will solve the disposal problem associated with this waste material. Also modified concrete paving blocks will reduce the CO2 emission because of less consumption of cement which intern will clean the environment. It may be also noted that the saving in cement will conserve the natural recourses and will reduce the energy demand needed in the production of cement. Hence, Utilization of brick kiln dust waste in concrete paving blocks will produce more sustainable concrete.

## References

[1] Shackel, B. (1982). "An Experimental research on the Factors Influencing the Design of Interlocking Concrete Block Pavements for Roads." ProcAust Road Res Board, 11: Part 2.

[2] Shackel,B. (1980). ―An Experimental Investigation of the Response of Interlocking Concrete Block Paving to Simulated Traffic Loading‖.

[3] Shackel, B. (1980). ―An Experimental Investigation on the importance of the Bedding sand and Jointing Sands in the Performance of Interlocking Concrete Block Pavements.‖ Concrete/Beton.

[4] Shackel, B. (1979)."A Design Method for Interlocking Concrete Block Pavements." on Precast Concrete Paving Block, Concrete Society of Southern Africa.

[5] Shackel, B., &Arora, M.G. (1979) "The Evaluation of Interlocking Block Pavements" a Conference on Concrete Masonry Association Sydney.

[6] Tighe, S., Chung, W. (2004). ―University Curriculum Interlocking Concrete Pavements, Module: Interlocking Concrete Pavements.‖ Developed for the Interlocking Concrete Pavement Institute, University of Waterloo

[7] Knapton, J. and Barber, S.D. (1979) ―The behavior of a concrete block pavement.‖ Proceedings of Institution of Civil. Engineers, 66, pp. 227-292.

[8] Algin, H. M., and Knapton, J. (1998). ―Research into the Performance of Interlocking Paver Pavements.‖ Proceedings of the Institution of Civil Engineers. Transport., 129(03), 142– 150.

[9] Croney, D., Croney, P. (1991). ―The design and performance of road Pavements.‖ Second Edition.

[10] ICPI (2007). ―Selection of bedding sand for Interlocking Concrete Pavements in Vehicular Applications.‖ Tech Spec 17, Interlocking Concrete Pavement Institute, Washington, DC, U.S.A.

[11] J. Guidelines for the use of Interlocking Concrete Block Pavement, IRC: SP 63-2004, The Indian Road Congress, New Delhi 110011

[12] G.R.Rada, D.R.Smith, " Interlocking Concrete Pavement in North America: A Performance Evaluation Study", Segmental Concrete System Association Sterling, Verginia, USA

[13] B. Shackel, D. O. Ooi Lim, "Mechanism of Paver Interlock" School of Civil and Environmental Engineering", University of New South Wales, L & M Foundations, Singapore, ASCE

[14] B.Shackel, "The design of interlocking concrete block pavements for road traffic", National Institute for Transport and Road Research, CSIR, South Africa, ASCE

[15] S.D. Barber and J. Knapton, "An Experimental investigation of the behaviour of a concrete block pavement with sand sub-bas", Proc. Inst. Of Civil Eng., 69(2), 139-155 (1980)