Sustainability, Agri, Food and Environmental Research, (ISSN:0719-3726), 12(X), 2024:
http://dx.doi.org/10.7770/safer-V12N-art779

Interlocking concrete block pavement as an alternative to flexible and rigid pavement in medium traffic condition: comparative assessment based on sustainability.

Pavimento de bloques de hormigón entrelazados como alternativa al pavimento flexible y rígido en condiciones de tránsito medio: evaluación comparativa basada en la sostenibilidad.

Jacob C Babu, Anisha Anil, Akshaya V Kumar, Anjali Vijayan, Tiju Susan Thomas, Dr. Dhanya B.S.
Department of Civil Engineering, Rajiv Gandhi Institute of Technology, APJ Abdul Kalam Technological University, Kottayam, Kerala, India.
Corresponding author's email: jacobbabu14@gmail.com (Jacob C Babu)

ABSTRACT

Highway pavements are one of the most energy and resource intensive infrastructures in the world. Hence, studies related to sustainability of pavements are gaining much importance. Interlocking Concrete Block Pavement (ICBP) is a widely accepted technology used extensively for constructing parking lots, walkways and roads. Compared to other conventional pavement methods, ICBP has many advantages such as less maintenance cost, high dimensional accuracy and will not be affected by thermal expansion and contraction. At present, the researches dealing with ICBP are focused mainly on the structural aspects only. However, it is necessary to study a pavement system in terms of its structural, environmental and economic aspects. Through this work, an attempt is made to study all these three aspects of ICBP which is meant to carry medium traffic. The design of ICBP was carried out based on IRC SP63: 2018. Both rigid and flexible pavement systems for the same traffic conditions were designed following IRC58: 2015 and IRC37: 2018 respectively. Comparison of these three pavement systems were carried out in terms of their material, construction as well as environmental aspects. Cradle to gate Life Cycle Assessment (LCA)of three pavement systems were studied using OpenLCA software. The economic aspect was evaluated by preparing material quantity estimates assuming single lane road for a 10m stretch. The results indicate that ICBP is a competitive option to rigid and flexible pavements in medium traffic conditions.

Keywords: sustainability, pavement, concrete, paver block, traffic.

RESUMEN

Los pavimentos de carreteras son una de las infraestructuras que consumen más energía y recursos del mundo. De ahí

que los estudios relacionados con la sostenibilidad de los pavimentos estén ganando mucha importancia. El pavimento de bloques de hormigón entrelazados (ICBP) es una tecnología ampliamente aceptada que se utiliza ampliamente para la construcción de estacionamientos, pasarelas y carreteras. En comparación con otros métodos de pavimento convencionales, ICBP tiene muchas ventajas, como menos costos de mantenimiento, alta precisión dimensional y no se verá afectado por la expansión y contracción térmica. En la actualidad, las investigaciones relacionadas con el ICBP se centran principalmente en los aspectos estructurales únicamente. Sin embargo, es necesario estudiar un sistema de pavimento en términos de sus aspectos estructurales, ambientales y económicos. A través de este trabajo, se intenta estudiar estos tres aspectos del ICBP destinado a transportar tráfico medio. El diseño del ICBP se realizó con base en IRC SP63:2018. Tanto los sistemas de pavimento rígido como flexible para las mismas condiciones de tráfico se diseñaron siguiendo IRC58:2015 e IRC37:2018 respectivamente. Se llevó a cabo una comparación de estos tres sistemas de pavimento en términos de su material, construcción y aspectos ambientales. Se estudió la evaluación del ciclo de vida (LCA) de la cuna a la puerta de tres sistemas de pavimento utilizando el software OpenLCA. El aspecto económico se evaluó mediante la preparación de estimaciones de cantidad de material asumiendo un camino de un solo carril para un tramo de 10 m. Los resultados indican que el ICBP es una opción competitiva frente a pavimentos rígidos y flexibles en condiciones de tránsito medio.
Palabras clave: sostenibilidad, pavimento, hormigón, adoquín, tráfico.

INTRODUCTION

In this modern construction era, transportation plays a major role in the economy. Pavements are inevitable component of transportation. The primary function of a pavement is to distribute the vehicular loads to the sub-grade through different layers. The pavement layers include compacted sub-grade, sub-base course, base course, binder course, and surface course. Characteristics of a good pavement include sound structural strength, adequate skid resistance, smooth level surface to ensure riding quality, appropriate light reflecting characteristics, long life with low maintenance, less noise pollution etc. Thus, the design criteria of pavements include load bearing ability, durability, safety, climatic conditions, sub-grade characteristics, maintenance and cost. There are different types of pavement systems viz. Flexible, rigid and interlocking concrete block pavement systems. Flexible pavements comprise ofa mixture of bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the sub-grade. Rigid pavements are composed of plain cement concrete or reinforced cement concrete slab placed over a sub-base layer. Interlocking concrete block pavements are composed of factory-made block units placed over a layer of bedding sand and joints between the blocks filled using joint sand. The entire block layer is placed over appropriate sub-base layer. Among the 58.98 lakh km road network in India 90% are of flexible pavement. [1]

Interlocking Concrete Block Pavement (ICBP) was introduced in Netherlands in the early 1950s. These are widely used in locations where conventional pavements are not suitable. ICBPs are mostly used in areas like footpaths, platforms, parking lots, residential roads, desert roads and locations subject to settlement. These can also be used in heavy traffic locations such as ports, harbour, airports, container terminals, etc. (Unilock specifications on interlocking concrete pavements). ICBP has many advantages compared to traditional methods, which include speedy construction, easy maintenance, economy, aesthetically attractive, high drainage capacity etc. As the blocks are mass produced at the factory under better quality control, it is possible to ensure the quality, strength, and dimensional accuracy of blocks. Interlocking concrete block pavement differs from other pavements according to their mechanical behaviour, manufacturing technique, structural design, installation technique and structural behaviour.They have much similarity to flexible pavement as they are dependent on an aggregate base and uniform sub-grade to support imposed loads. Like flexible pavements, these can accommodate minor settlements and occasional overloads. All these points towards the fact that ICBP can be a good substitute for conventional pavements in low or medium traffic conditions.[2]

In India, ICBP is designed following IRC SP63: 2018 [3] design catalogue. Furthermore, most of the studies mainly focus on the structural aspects of the pavements, while the environmental factors being neglected. Since the future demands systems which are sustainable, the studies should focus on all the key elements of sustainability such as environment and economy along with the structural aspects. Thus, the current paper does a comparative study of ICBP with traditional pavement systems such as rigid and flexible pavements in medium traffic conditions. Sustainability aspects of the different pavement systems are also exploited by studying structural, environmental and economy aspects.

METHODOLOGY

The methodology adopted for the present study include design of flexible, rigid and interlocking concrete pavement systems for same traffic conditions and sub soil conditions, followed by their analysis on environmental and economic aspects. Design of three pavement systems were done following the corresponding IRC standards. In order to study the economic aspects, estimate of the designed pavements were done by assuming a single lane road of 3.75m width and 10m length following CPWD schedule of rates (2019) [6]. The environmental aspects of all the three pavements were compared using cradle to gate LCA in OpenLCA software. Comparative assessment of the entire three pavement systems were carried out considering all the three aspects mentioned above.

DESIGN OF PAVEMENT SYSTEMS

All the three pavements are designed for same traffic conditions and CBR value of soil.The design traffic is taken as of 20 Million Standard Axle (msa) and CBR value for the subgrade is taken as 8%.

i. Design of Interlocking concrete block pavement:

The design of interlocking concrete block pavement was done based on IRCSP63: 2018 [3] design catalogues. Traffic category of a pavement decides the block grade designation and thickness of underlying layers. Compressive strength of blocks is chosen as 40 N/mm2 as per table 1 of IS 15658:2006 [7]. Designed interlocking concrete block pavement is shown in Fig. 1.

The designed ICBP was composed of granular sub-base layer of 200mm, over which 250mm WMM layer is laid. Paver blocks of 80 mm thick are laid over 30 mm thick bedding sand to carry design traffic of 20 msa. Mix proportioning of paver blocks was done based on IRCSP 63: 2018 [3]. Obtained proportions are shown in Table 1.Any other data required for design was collected from ICBP manufacturers.

ii. Design of flexible pavement:

The design was carried out based on IRC37: 2018 [5]. The design period considered was 15 years. From the catalogue given in IRC37:2018 [5], thickness of different layers were assumed. After finalizing the design parameters, those were input into the design software known as IITPAVE software to calculate the induced strains at critical points. Table 2 shows the design inputs to IITPAVE software. The allowable strain value for the pavement was obtained from IRC37: 2018 [5] and it is then compared with actual strain values obtained from IITPAVE. The allowable and actual strains at critical points are shown in Table 3. Since actual strain is less than allowable strain, it can be inferred that opted thickness of each layers are safe to carry the design traffic. The designed flexible pavement is shown in Fig. 2. The pavement was composed of 200 mm thick granular layer, over which there is 250 mm thick wet mix macadam. Bituminous layers are composed of 90 mm thick dense bituminous macadam and 30 mm thick bituminous concrete. Prime coat and tack coat layers are applied over Wet Mix Macadam (WMM) and seal coat over bituminous concrete. Proportioning of layers of flexible pavements was done by specifications of MoRTH,2013 [8]. The obtained proportions are shown in Table 4. Bituminous layers are mainly composed of coarse aggregates, fine aggregates and bitumen as binder. Granular layers are mainly composed of coarse and fine aggregates, where as in WMM, optimum water is added to obtain desired density.

TABLE 1. MIX PROPORTIONS FOR PAVER BLOCKS (FOR 1 M3)

Material	Quantity
Cement	449 kg/m3
Fine aggregate	1480 kg/m3
Coarse Aggregate (6mm and down)	747 kg/m3
Water	94 kg/m3

TABLE 2. DESIGN INPUTS FOR IITPAVE

Pavement layers	Thickness (mm)	Modulus of Resilience(MPa)	Poisson's ratio
Sub-grade	---	66.60	0.35
Granular	450mm	208.18	0.35
Bituminous	120mm	4000	0.35

TABLE 3. COMPARISON OF ACTUAL STRAIN WITH ALLOWABLE STRAIN

Strain	Allowable strain (IRC:37-2018)	Actual strain (IITPAVE)	Remark
Horizontal tensile strain	0.263 x 10-3	0.1889 x 10-3	Safe
Vertical compressive strain	0.580 x 10-3	0.4374 x 10-3	Safe

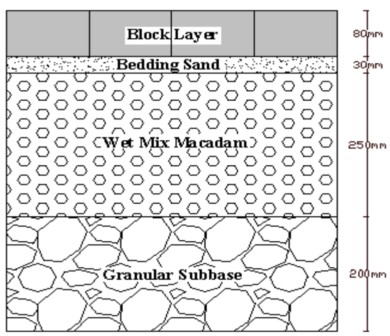
TABLE 4. MIX PROPORTIONS OF FLEXIBLE PAVEMENT LAYERS

Pavement Layer	Material	Quantity /Proportion
Bituminous Concrete	Coarse Aggregate	50%
	Fine Aggregate	45%
	Filler	5%
	Bitumen	10 % by weight of total mixture
Dense Bituminous Concrete	Coarse Aggregate	65%
	Fine Aggregate	30%
	Filler	5%
	Bitumen	10 % by weight of total mixture
Wet Mix Macadam	Coarse Aggregate	70%
	Fines	30%
	Water	6%
Granular Subbase	Coarse Aggregate	60%
	Fine Aggregate	40%

iii. Design of rigid pavement:

The cement concrete pavement without tied concrete shoulders is designed for 20msa design traffic and having lane width of 3.75m with transverse joint spacing of 4.5m. Design period of pavement is taken as 30 years.

As per IRC58[9], for subgrade of 8% CBR, modulus of subgrade reaction is taken as285MPa/m. The cumulative fatigue damage values obtained for bottom-up and top-down cracking for trial thickness 260mm analyses are given in Table 5.As the total cumulative fatigue damage value of BUC and TDC obtained is less than 1, the trial thickness 260mm is adequate. The rigid pavement was designed with 260mm pavement quality concrete layer, 150mm Dry lean concrete (DLC) sub base and 250mm wet mix macadam separating the subgrade layer and DLC layer. The designed rigid pavement is shown in Fig. 3. Mix proportioning of M40 grade concrete for the concrete slab is done following IRC:44-2017 [10]. Proportioning of DLC layer and WMM layer was done using MoRTH specifications (2013) [8]. Obtained mix proportions are shown in Table 6. Cost of the designed pavements was estimated by assuming a single lane road of 3.75m width and 10m length. PWD schedule of rates [11], Raipur and Delhi Analysis of Rates (DAR) [12] was followed for preparing the same. The material quantity was calculated according to the design parameters taken or assumed. Overall construction cost comparison of ICBP, flexible and rigid pavements are shown in Fig. 4. From Fig. 4, it can be inferred that the cost of ICBP is 5.45% lesser than flexible and 8.56% lesser than rigid pavement.



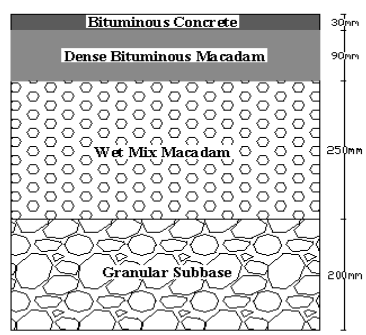
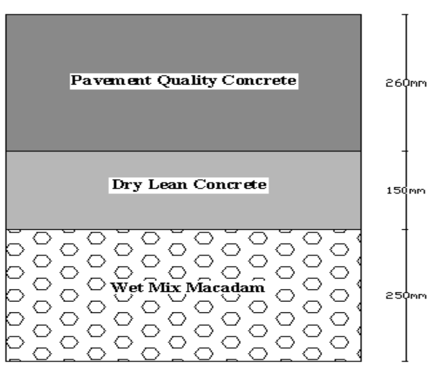


Fig.1 Designed interlocking concrete block pavement Fig. 2. Designed flexible pavement



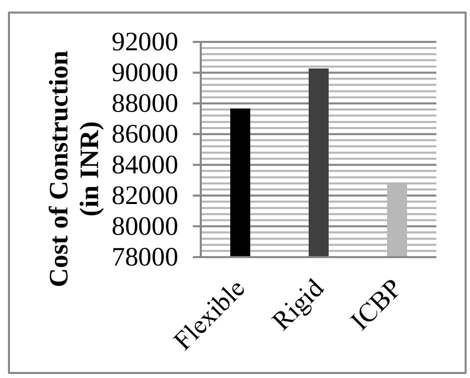


Fig. 3. Designed rigid pavement Fig. 4. Cost comparison of designed pavements

LIFE CYCLE ASSESSMENT

Life cycle assessment is a well-established sustainability evaluation tool to identify the environmental impact of a product or service. ISO 14040 [13] series of standards provides a generalized framework for LCA. Instead of giving a broad methodological guidance, the standards provide general guidance for performing a well-documented and transparent LCA of different products. LCA studies comprise of four major steps Goal and Scope Definition, Inventory Analysis, Impact Assessment and Life Cycle Interpretation.[14]

A. Goal and Scope Definition

The main goal of this LCA study was to compare the environmental performance of ICBP, rigid and flexible pavement. This study also helps to identify different and most important phases in pavement construction. Being a comparative study, a full life cycle analysis was not carried out. A small stretch was considered as functional unit, thus considering only the mainline pavements, whereas side shoulders and drainage system were not considered. The scope of this study includes,

a) Functional Unit: 1 m2 pavement is taken as the functional unit, raw materials and other energy inputs are calculated for this unit.

b) System Boundaries: Following cradle to gate approach of LCA, process from raw material extraction upto the construction of pavement was chosen as the boundaries. As the database was not available for labour charges, it was not included in the study.

TABLE 5. THE CUMULATIVE FATIGUE DAMAGE VALUES OBTAINED FOR BOTTOM-UP AND TOP-DOWN CRACKING

Cumulative fatigue Damage	Bottom up cracking (BUC)	Top down cracking (TDC)
Due to rear single axle	0.412	0.194
Due to tandem axles	0.299	0.05
Total	0.711	0.244
Grand total	0.955 < 1	

TABLE 6. MIX PROPORTIONS OF CONCRETE SLAB AND DRY LEAN CONCRETE LAYER

Pavement Layer	Materials	Quantity
Concrete Slab	Cement	444 kg/m³
	Water content	160 L
	Fine Aggregate	590 kg/m³
	Coarse aggregate	1242 kg/m³
	Water-Cement Ratio	0.36
Dry Lean Concrete	Cement	150 kg/m³
	Water content	136.5 L
	Fine Aggregate	780 kg/m³
	Coarse aggregate	1170 kg/m³

TABLE 7. ABSTRACT OF COST OF FLEXIBLE PAVEMENT

c) Sl. No. d)	Particulars	Quantity	Unit	Rate (Rs.)	unit	Amount (Rs.)
1	Preparation of Subgrade	40	m2	156.75	m2	7461.2
e) 2	Laying of granular subbase	8	m3	1398	m3	10960
f) 3	Laying of WMM	15	m3	1483	m3	21795
4 g)	Applying tack coat	37.5	m2	11	m2	412.5
5	Laying DBM	5.4	m3	5946	m3	31465.8
h) 6	Laying of BC	1.8	m3	7635	m3	13467.6
7	Applying seal coat	37.5	m2	10	m2	450
i) 8	Applying Prime coat	37.5	m2	45	m2	1650
j)					Total	87662.1

TABLE 8. ABSTRACT OF COST OF RIGID PAVEMENT

Sl. No.	Particular	Quantity	Unit	Rate Rs.	unit	Amount Rs.
1	Preparation of Subgrade	40	m2	156.75	m2	7461.2
2	Laying of WMM	12.8	m3	1483	m3	18598.4
3	Laying of DLC	5.625	m3	2319	m3	12785.6
4	Laying of PQC	9.75	m3	4916	m3	46975.5
5	Geotextile Separation layer	75	m2	59	m2	4425
					Total	90245.7

B. Inventory Analysis

The main phases in inventory analysis are material requirements, equipment requirements and transportation of those materials to site. Materials required for each system of pavement is calculated from the structural design and mix design results of pavements. The quantities of materials to be gathered for the construction of pavement systems are shown in Table 7. In order to check overall burden on the environment due to pavement construction, transportation of those materials to the site also need to be considered. Transportation of materials from source to site in kilometers is shown in Table 8. Site considered for the study is Pampady, Kottayam. Pavement construction involves the use of set of huge equipment and plants. Various sets of equipment used as its specifications are given in Table 9. [19]

C. Impact Assessment

Cradle to gate LCA results for three pavements are obtained based on the impact categories, ecosystem quality, human health and resources using impact assessment method ReCiPe. The results obtained from OpenLCA software for each process of construction of the pavements is shown in Fig. 5-7. It is clearly visible that bitumen production affects resources mainly and quarry operation affects ecosystem quality in flexible pavement construction, meanwhile in rigid pavement quarry operation and cement production phase causes more burden to environment. It can be seen that in ICBP also quarry operation and cement production phase causes more burden to environment like rigid pavement as shown in Fig. 8, since materials used for pavement construction are the same.[30]

D. Interpretation

The overall impact assessment results of the pavements are shown in Table 10. Category wise impact assessment of each pavement is shown in Fig. 8 and overall impact assessment is shown in Fig. 9. Ecosystem quality is mainly affected by rigid pavement construction due to the need of high quantities of aggregates and cement, whereas the effect of ICBP and flexible pavements are comparable. Similar trend can be observed in the case of human health also, whereas resources are mainly affected by the construction of flexible pavement due to the bitumen production phase [26].

Here the impact value of rigid pavement is high following flexible and then ICBP. It is due the variation in the materials and process in construction as well as due to the quantities of materials used. Also, the study was considered upto construction phase only; hence the long-term benefits of concrete or concrete block pavements were not accounted in this study. Thus from LCA study the environmental performance of ICBP is better than other two conventional systems.[15]

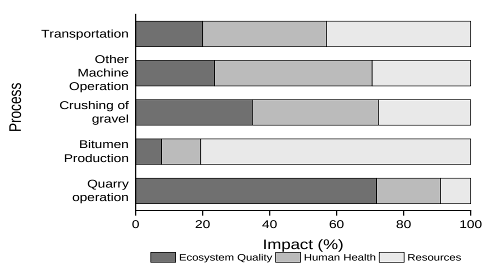
COMPARISON OF PAVEMENT SYSTEMS

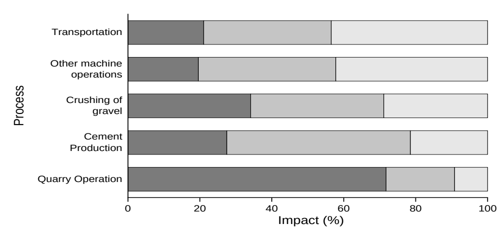
Based on studies conducted and literature review, comparison made among ICBP, flexible and rigid pavements are shown in Table 11. Most of the criteria are satisfied by ICBP, showing its potential to be used instead of conventional systems. In certain aspects like noise generation, ICBP is inferior to flexible and rigid pavement but methods like widening joint gap, using special kind of joint sand etc. can be utilized to overcome such drawbacks. Hence, it can be concluded that ICBP is a competitive option to rigid and flexible pavements in medium traffic conditions. Relevant factors are discussed in the table given below.

Criteria	Flexible Pavement	Rigid Pavement	ICBP

Criteria	Flexible Pavement	Rigid Pavement	ICBP
Design	Design mainly depends upon imposed traffic and soil condition	Design depends upon a variety of parameters such as Traffic, CBR, temperature differential	Design depends on imposed traffic and CBR
Design Period	15 years	30-40 years	20 years
Cost	Low construction cost; High maintenance cost	High construction cost	Lowest construction as well as maintenance cost
Drainage	Drainage layer provided immediately above subgrade , side drains are also connected to this layer	Subbase drainage layers and side drains are provided	Subbase layers and side drains are provided. Special types of joint sands are incorporated to avoid leaking of joint sand with surface flow.
Maintenance	Maintenance (including overlay, if required) requires intensive labour and high quantity of materials.	Maintenance such as slab restoration and stabilization etc. requires intensive efforts similar to flexible pavement	Maintenance is of less labour intensive and defects are localized. Many times removal of small portions and reinstallation is required.
Noise	Produce less noise compared to other systems, Noise can be further reduced by decreasing nominal size of aggregate	Noise generated is comparatively higher than flexible but surfaces subjected to diamond ground produce similar levels noise to that of flexible	Noise generated is higher due high stiffness of blocks, but can be reduced by widening the joint gap and adding rubber modified materials as fillers in the gap

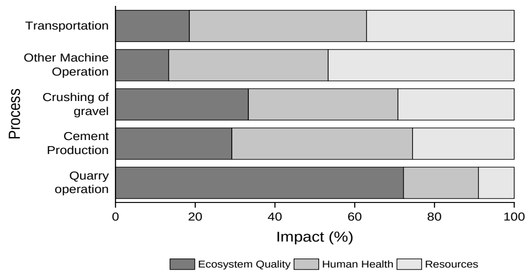
Criteria	Flexible Pavement	Rigid Pavement	ICBP	
Safety	Offer high skid resistance, smooth and comfortable driving.	Smooth and comfortable riding with better visibility	Slight vibration can be felt while travelling but it attracts more attention of driver	
Colour	High colour contrast with markings provide feel of safety but chances fading high.	Pigments can be added and permanent markings can be made possible	Available in a variety of colours and can be laid in a pattern instead providing further markings which is of permanent nature	
Weather Condition	Sensitive to high temperature condition and not suitable in water logged areas	Sensitive to temperature and produce many defects, but suitable in water logged areas.	Surface temperature is lowest and suitable in water logged areas.	[8][16][17][18][19][20][21]
Installation	Requires the use of heavy equipment and plants like HMA plant, WMM plant, Pavers, Rollers etc.	Requires the use of heavy equipment and plants like mixing and batching plant, rollers, pavers, backhoe, bulldozers etc.	Requires equipment such as rollers, backhoe, bulldozers etc. Since the blocks are factory made product, comparatively equipment use less and hence requires less labour.	





.

Fig. 5. Process wise impact assessment of flexible pavement Fig. 6. Process wise impact assessment of rigid pavement



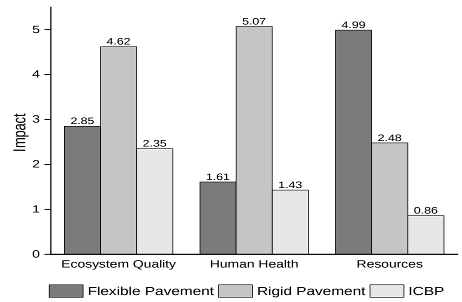


Fig.7. Process wise impact assessment of ICBP Fig. 8. Category wise impact assessment

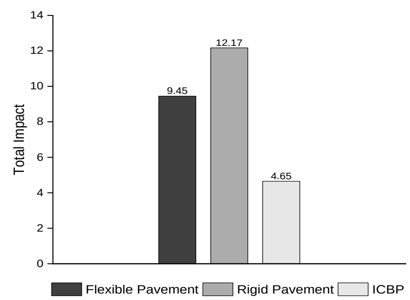


Fig. 9. Overall impact assessment

TABLE 9. ABSTRACT OF COST OF ICBP

Sl. No.	Particular	Quantity	Unit	Rate Rs.	unit	Amount Rs.
1	Preparation of Subgrade	40	m2	156.75	m2	7461.2
2	Laying of granular subbase	8	m3	1398	m3	10960
3	Laying of WMM	15	m3	1483	m3	21795
4	Laying of 80 mm thick CC block over bedding sand	37.5	m2	953	m2	42525
					Total	82741.2

TABLE 10. INPUT MATERIALS FOR LCA

Flexible Pavement		Rigid Pavement		Interlocking Concrete Block Pavement	
Item	*Quantity*	*Item*	*Quantity*	*Item*	*Quantity*
Coarse Aggregate	828.72 kg	Coarse Aggregate	817.06 kg	Coarse Aggregate	708.54 kg
Fine Aggregate	436.47 kg	Fine Aggregate	406.96 kg	Fine Aggregate	505.98 kg
Water	34.14 L	Water	89.38 L	Water	41.44 L
Bitumen	27.96 kg	Cement	137.94 kg	Cement	35.02 kg

TABLE 11. TRANSPORTATION DISTANCE OF INPUT MATERIALS

Item	From	To	Distance
Coarse Aggregate	Quarry site*	Construction Site*	5.1 km
Fine Aggregate	Quarry site	Construction Site	5.1 km
Bitumen	Refinery*	Construction Site	67 km
Cement	Quarry site*	Construction Site	201 km

*Quarry site for aggregates –Makkalpady, Pampady, Kerala, India

*Quarry site for Cement - Thalaiyuthu, Sankar Nagar, Tamil Nadu, India

*Refinery – Cochin, Kerala, India*Construction Site – Pampady, Kerala, India

TABLE 12. EQUIPMENT AND SPECIFICATION

Equipment	Capacity	Power
Hot asphalt Plant	60 - 90 TPH	Greater than 75.4 kW
Mobile Concrete Mixer	30 m3/hr	18.6 - 75.4 kW
Asphalt Paver	150 TPH	18.6 - 75.4 kW
Concrete Paver	150 TPH	18.6 - 75.4 kW
Vibrating Roller	4 km/hr	Greater than 75.4 kW
Bulldozers	32 ton	Greater than 75.4 kW
Backhoe	0.7 m3	Greater than 75.4 kW
WMM plant	100 TPH	- 75.4 kW

TABLE 13. CATEGORY WISE IMPACT ASSESSMENT TABLE OF THE PAVEMENTS

Impact category	Flexible pavement	Rigid pavement	Interlocking concrete block pavement
Ecosystem Quality	2.85	4.62	2.35
Human Health	1.61	5.07	1.43
Resources	4.99	2.48	0.86
Total	9.45	12.17	4.65

CONCLUSION

In order to bring out the hidden potential of interlocking concrete block pavement as a sustainable pavement system, a comparative study of ICBP with flexible and rigid pavement is conducted on medium traffic condition of 20msa. Design data, environmental analysis, estimation and literature studies lead to the general conclusion that ICBP is a competitive option to rigid and flexible pavements in medium traffic conditions. Following are the specific conclusions.

a) Structural design of pavement systems shows that pavement layers of ICBP is much similar to flexible pavements except at the wearing course/surface course.

b) For same traffic condition, the quantities of materials, equipment, and labour is less for ICBP than flexible and rigid pavements.

c) Estimation of a single lane road of 10 m length had resulted in the conclusion that ICBP is more economical in terms of construction than other two pavements.

Sustainability assessment was done by cradle to gate LCA. Long term effects of the pavements are not mentioned due to the lack of availability of data. Each phase of pavement construction has its own contributions and the bitumen production, quarry operation and cement production stages cause more impact on environment. As ICBP is a factory-made product and requires less quantity of materials, environmental impact is less during its construction in comparison with rigid and flexible pavements. Comparison of pavements based on various criteria shows that ICBP is either superior or met the standards of flexible and rigid pavement in design, cost maintenance, drainage, safety, colour and installation criteria’s. Whereas in noise generation ICBP is inferior to conventional systems, but it can be resolved by applying modifications like widening joint gap, using special kind of joint sand etc. Hence ICBP is a potential alternative to conventional systems if properly utilized. Even though there are design catalogues for ICBP design in IRC, it is not sufficient for a complete pavement design. In standards, there are explanations for construction and mix design details of each layers of conventional systems of pavements, whereas ICBP is not even mentioned in many of the standards.

A thorough design procedure involving various design parameters cannot be found in any of the Indian standards. So there is a huge need of proper construction as well as design methodology of ICBP considering Indian scenario, then only the pavement can be used, utilizing its full potential.

REFERENCES

Introduction to life cycle assessment, 2021. https://www.google.com/url?sa=tandsource=webandrct=jandurl=http://lab.fs.unilj.si/kes/erasmus/LCAIntroduction.pdfandved=2ahUKEwiPuOSq25bxAhWXWX0KHcPzBe0QFjAAegQIAxACandusg=AOvVaw1oQTqlfBVaCiXDDz7U1EUVand cshid=1623659607455/(accessed 13 june2021)

Design Considerations for Interlocking Concrete Pavements, Unilock Specifications, Unilock interlocking concrete paver design guide, 2021. https://3vfdf1d71bfa9odb2zenhe14-wpengine.netdna-ssl.com/wp-content/uploads/sites/10/mp/files/assets/files/design-considerations-interlocking-pavements17.pdf/(accessed 13 june2021)

IRC:SP:63-2018, Special publication – Guidelines for the Use of Interlocking Concrete Block Pavement, Indian roads congress.

IRC:58-2015– Guidelines for the design of plain jointed rigid pavements for highways, Indian roads congress.

IRC:37-2018– Guidelines for the design of flexible pavements, Indian roads congress.

Analysis of Rates for Delhi - 2019, Government of India,Central Public Works Department

IS: 15658-2006, Precast concrete blocks for paving –specification, Bureau of Indian Standards, New Delhi.

MoRTH - 2013, Ministry of road transport and highways – Specifications for road and bridge works (Fifth Revision)

IRC:58-2015, Guidelines for the design of plain jointed rigid pavements for highway (Fourth Revision)

IRC:44-2017– Guidelines for cement concrete mix design for pavements, Indian roads congress.

Quality Control Manual - 2015, Government of Kerala Public Works Department

Schedule of Rates for Road and Bridge works - 2019, Government of Chhattisgarh Public Works Department.

IS/ISO: 14040-2006, Environmental Management-Life cycle assessment-principles and framework, Bureau of Indian Standards, New Delhi.

Baumann, H., and Tillman, A. M. (2004). The hitch hiker's guide to LCA.https://doi.org/10.1065/lca2006.02.008

Singh, A., Vaddy, P., and Biligiri, K. P. (2020). Quantification of embodied energy and carbon footprint of pervious concrete pavements through a methodical lifecycle assessment framework. Resources, Conservation and Recycling, 161, 104953.https://doi.org/10.1016/j.resconrec.2020.104953

Chaddha, S., Chauhan, A. S., and Chawla, B. (2017). A study on the rigid pavement construction, joint and crack formation. International Journal of Modern Trends in Engineering and Research, 4(1), 138-143.

Gunatilake, D. and Mampearachchi, W.K., (2017), Finite element modelling approach to determine optimum dimensions for interlocking concrete blocks used for road paving, Road Materials and Pavement Design , pp. 1-17.https://doi.org/10.1016/j.jenvman.2009.06.018

Jamshidi, A., Kurumisawa, K., White, G., Nishizawa, T., Igarashi, T., Nawa, T., and Mao, J. (2019). State-of-the-art of interlocking concrete block pavement technology in Japan as a post-modern pavement. Construction and Building Materials, 200, 713-755. https://doi.org/10.1016/j.conbuildmat.2018.11.286

Kanawade, B., and Nawale, S. (2018). Strength and durability of concrete paver block. NDT test for bridges.

Di Mascio, P., Moretti, L., and Capannolo, A. (2019). Concrete block pavements in urban and local roads: Analysis of stress-strain condition and proposal for a catalogue. Journal of Traffic and Transportation Engineering (English Edition), 6(6), 557-566.https://doi.org/10.1016/j.jtte.2018.06.003

Mohod, M. V., and Kadam, K. N. (2016). A comparative study on rigid and flexible pavement: A review. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 13(3), 84-88.

Shackel, B., and Candy, C. C. (1988, May). Factors influencing the choice of concrete blocks as a pavement surface. In Proc., 3rd Int. Conf. On concrete block paving (pp. 78-85).

Received: 27th March 2023; Received: 03th August 2023; First distribution: 01th January 2023.