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Design And Reliability Analysis of Polymer Pervious Concrete Mix for Preparation of Paver Block

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Abstract

Porous concrete is a specially designed kind of concrete featuring high water porosity, allowing water to readily move through the already present interconnecting vast porous structures. The present experimental study emphasized on the production of permeable concrete with a lower Portland cement and recycled aggregate aggregates building environmentally friendly permeable pavements. The literature review suggested in most of the studies the use of single size of aggregate in the pervious concrete. This yields a bigger air space in comparison to normal concrete which leads to an increasing infiltration rate. The goal of the current research is to create a PIPB and analyze its structural, functional, and mechanical characteristics. Pore size distribution, porosity, dynamic elasticity modulus adopting UPV, strength properties, as well as wear by Cantabro loss are used to describe the PIPBs (CL) characteristics. Further, the assessments of density and porosity have also been varied, however, no evidences are observed that mix qualities influence. To summarize, a significant correlation has been observed between the CS and UPV as well as CL measures.

Keywords: Cantabro loss, compressive strength, pavement, tensile strength, Portland cement. thermoplastic

INTRODUCTION

Background

Stormwater is constantly expanding as there are more constructed amenities, like homes and businesses, as well as diminishing permeable, unpaved open spaces. As a result, the drainage system becomes overworked, also flash floods are unavoidable, disrupting road traffic and flooding sub-terranean parking lots and retail malls [1]. India's roadways have several issues, including runoff and waterlogging. An engineering solution is required to regulate rainwater runoff in metropolitan areas to prevent flash floods. The outcomes could be more positive if pervious concrete is employed in certain regions. There are significant environmental advantages if by-products like fly ash and slag are used in place of cement. Pervious concrete is used to build the pavements so that rainfall may be collected and appropriately led into the earth [1,2]. However, compared to ordinary concrete pavement, the strength of pervious concrete pavement has decreased. In more and more places throughout the world, pervious concrete is being used to build parking lots, secondary roads, driveways, sidewalks, and walkways. The pervious concrete is essential in recharging stormwater since it collects a sizable volume of rainwater and allows it to soak into the earth [3].

Due to its capacity to endure the many adverse effects that standard impermeable pavements experience, one such innovative roadway option that is essential to robust and environmentally friendly designs is pervious concrete pavement

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(PCP) [4]. It generally comprises a structural surface wearing course that permits rainwater penetration into a subordinate granular foundation or sub-base that sits on top of soil subgrade and is comprised of water, cement, coarse aggregates, and admixtures in particular proportions and is frequently referred to as a reservoir layer [1].

Pervious Concrete

Portland cement, aggregate, and water are combined to create pervious concrete, which has enough porosity to let water seep into the subgrade. It varies from traditional concrete in that the amount of fine aggregate is often reduced. In pervious concrete, there is often only one size of aggregate, which creates a wider air space than in regular concrete, increasing the rate of water infiltration [5].

Few or no fine particles are used in pervious concrete, aka porous concrete (due to increased porosity) or gap-graded concrete. Mixtures for pervious concrete are made up of cement, water, and a particular size of coarse aggregates, (with a water-to-cement ratio between 0.3 and 0.4) [6]. According to ASTM C39 compression strength tests, the compressive strength after 28 days of curing of such mixtures ranges from 800 psi to 3,500 psi. Additionally, different batch manufacturers produce pervious concrete mixes with various strengths and permeability rates [7].

A unique variety of concrete called pervious concrete has a high percentage of pores with a size of 2 to 8 mm or more. The permeability of pervious concrete typically varied from 15 to 30%, and the system of linked big holes allowed water to pass through the material without difficulty [8]. The mix specifications for pervious concrete pavements should be met by the pervious concrete mixtures.

LITERATURE REVIEW

Pervious concrete pavement (PCP) has been employed for as many as 30 years in both Europe and the United States [9]. Portland Cement Pervious Concrete (PCPC) is often used as a pavement surface for roads in Japan and Europe to reduce traffic noise and boost braking performance. Presently, full-depth PCPC is used in the U.S. to build parking lots, sidewalks, and sometimes low-volume roads [10].

By allowing rainfall to seep through the pavement, PCPC minimizes or perhaps eliminates the requirement for large-scale control structures, like retentive ponds. Furthermore, due to its large surface area, PCPC's make it easier for microorganisms to naturally attenuate, which reduces the number of pollutants in rainfall [11]. The overall quality of the water is improved since substances are confined in the pavement layers rather than accumulating in nearby water bodies and waterways.

Pervious concrete was suggested as a stormwater runoff management strategy in research that was done [12]. The authors suggested that pervious concrete ought to have a high air void percentage of 15% to 30%, a unit weight of 100 to 120 lbs/ft^3, as well as a compressive strength of 25-35MPa. According to the study, the infiltration rate should be 0.1–0.5 in/hr. The benefits of adopting pervious concrete and possible environmental catastrophes were also covered by the researchers. Pervious concrete installation placement and optimum procedures were discussed. The paper covers the life span, freezing, maintenance, and blockage, including time-to-time inspections of PCPs.

Methodology

Development of Pervious Interlocking Paver Blocks (PIPB) for light traffic roads as well as the evaluation of the effects of both aggregate grading and fines content on the mechanical characteristics of PIPB and load-bearing capacity of PIPB pavement structures are the main goals of the current research. Crushed limestone and river gravel were used as the two forms of single-sized coarse aggregate in the preparation of pervious concrete mixtures. These mixes comprised pea gravel that was readily accessible, single-sized aggregate (1/2-inch, 3/8-inch, and No. 4 sieve sizes), and single-sized aggregates with a low quantity of sand [8][13]. Additionally, the engineering features of pervious concrete were examined concerning the impacts of latex and silica fume. The present study has been performed in 2 phases.

Phase I began with the preparation of small-scale mixes to test the pervious concrete's characteristics after seven days. The temporal development of permeability, strength, freeze-thaw, flexural and compressive strength, and split durability are then assessed for a few selected mixes using large-scale mixes (Phase II) [14]. Additional assessments are the impacts of compaction on the engineering characteristics of pervious concrete.

The automated batching technique is used to combine the ingredients of the concrete. Since PIPB has a low water-cement ratio, trough and pan mixers are employed instead of drum mixers. A conveyor carries the mixed concrete to the mechanical pressing machine [4]. To compress the concrete and help it settle in the mould, the mixture was first vibrated. Following this, a hydraulic press with a maximum pressure of 10 MPa was used. A hydraulic conveyor is subsequently used to transport the compacted PIPB to the stackyard for air drying. The PIPB is water-cured 24 hours after it has been air-dried.

Materials and method

In India, there is increasing demand for the use of fly ash in buildings. The rising list of application sectors is one illustration of the growing concern about utilizing fly ash rather than disposing of it. Other than building, fly ash is used in a variety of industries, including agriculture, ceramics, and metallurgy. Fly ash is frequently used in the production of prefabricated materials like bricks and blocks, as well as in the construction of roads, embankments, landfills, and other structures [15]. Agriculture, plant nutrition, ceramics, balancing soil acidity, metal extraction, and other non-engineering uses are examples. Depending on the kind of coal and the resulting chemical analysis.

The CaO content in Class F fly ash is less than 10%, and it exhibits pozzolanic qualities [16]. Typically produced from the burning of anthracite coal. Water, coarse aggregate, and either OPC or PPC make up pervious concrete. To reduce surface area, the size of the coarse aggregate utilised should be homogeneous. It is also important to remember that the water and cement ratio should be between 0.25 and 0.35 [5]. Different specifications and standards of the concreate mixture are given in Table 1.

Table 1. Specification and standards of concrete mixtures [7,12,42]

Name	**ASTM C-618**	**European Specifications**			**IS 3812 2003 – I**
		En450	***En197- I***	***En3892 part I***	
Fi_2O_3+Al_2O_3+SiO_2 minimum	70	-	-	-	70
MgO, Maximum	-	-	-	-	70
Total alkalis, max.	1.5	-	-	-	1.5
SiO_2 minimum	-	-	-	-	35
SO_3, maximum	5	3	-	2	3
LOI (1hour) max.	6	5 - 7	5 - 7	7	5
Free CaO, maximum	-	1	1	-	-
Fineness micron, maximum	45	34	40	12	34
Lime reactivity, N/mm2	-	-	-	-	4.5
Reactive/soluble SiO2, min.	-	25	25	-	20
Autoclave, Percent	0.8	-	-	-	0.8
Total/reactive CaO	-	10	10	10	-
Blaines fineness m2 /kg min.	-	-	-	-	320
Soundness, LeChatelier, mm	-	10	10	10	10
Cement activity 28 days	75	75	-	80	80

For preparation, the automated batching technique is adopted to thoroughly mix various concrete ingredients. Owing to PIPB's low water-cement ratio [9], pan and trough blenders are utilised. A conveyor carries the mixed concrete sample to the hydraulic pressing machine.

Novel Paver Block Preparing Methodology

The adopted methodology used for the preparation of the paver block involved various steps. It starts with the preparation of mould (wooden) for the given dimensions. The step two involved the filling of normal concrete between the two moulds. After setting up (about 10-12 hours) the concrete in the given space the rectangular (inner) mould was removed safely. The rectangular mould then be filled with the pervious concrete and finally, the demoulding of the paver is done after about 24 hours. The complete methodology of the paver block formation is shown in Figure.1. Further, the dimension of the rectangular portion is given in Table 2.

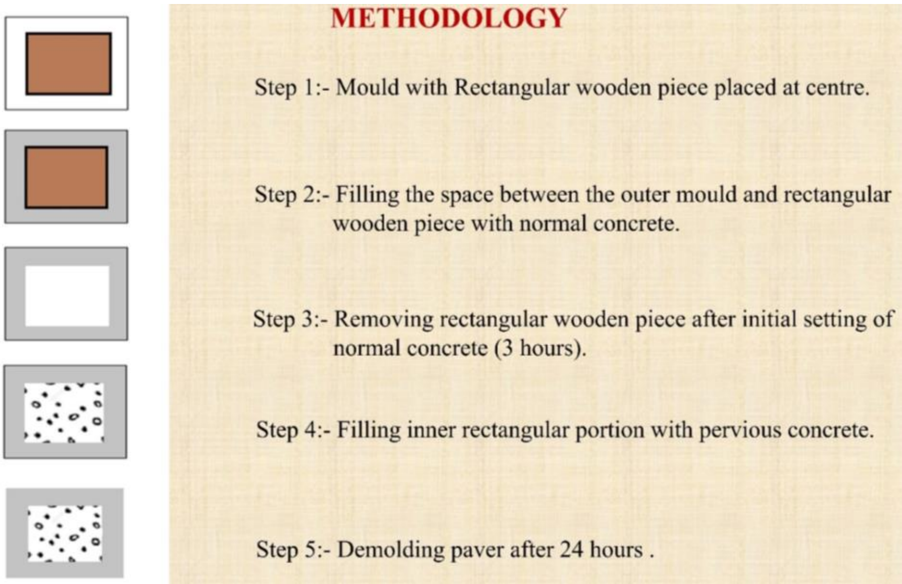

Figure 1. Method of preparing PIPB block [16]

Table 2. Dimension of inner rectangular portion [16]

Mix ID	Dimension of inner rectangular portion (mm)
NP50	50
NP100	100
NP150	150
NP200	200

Mix Design Data of Pervious Concrete

To understand the mix data of the pervious concrete, various statistics are presented and given in Table 3. During mixing, the cement having the OPC 53 grade is used which conforms to IS: 269. The coarse aggregate is utilized as per the IS-383r standard. The characteristics of these mixes are given in Table 4. The superplasticizer is used as 1% by weight of cement where W/C represents the water-cement ratio, and C/A represents the cement-to-aggregate ratio.

Table 3. Aggregate size and mixture percentage [10]

Single sized aggregate (mm)	Percentage (%)
10	50
6	50

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Table 4. Characteristics of different mix types [10]

S. n	Mix	C/A ratio	W/C	Cement (kg/m^3)	Water (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Sp (kg/m^3)	Permeablity (cm/sec)	Porosity	Compressive strength block (mpa)
1	m1	0.27	0.25	350	87.5	1296	nil	3.5	1.31	14.4	18.8
	m2		0.27		94.5				1.42	16	18.6
	m3		0.3		105				1.44	17.8	14

Mix Design Data of Normal Concrete

Similar to pervious concrete, normal concrete has utilized the cement with OPC 53 grade which conforms to IS: 269. The coarse aggregate with 19mm is used which also satisfies. As per IRC 44. For fine aggregate, Zone-II is utilized which also satisfies the IRC-44 & IS383. Table 5 and Table 6 give the mixture definitions data based on IRC-44 and IS-383. The specific gravity of fine aggregates, coarse aggregates, admixture and cement are 2.65, 2.72, 1.15 and 3.15 respectively.

Table 5. Mixture definitions based on IRC-44 and IS-383 [5,10]

IS Sieve Designation	Percentage Passing for Zone -II	
	As Per IRC-44 & IS383	***Fine Aggregate***
9.50mm	100	100
4.75mm	90 – 100	94.62
2.36mm	75 – 100	84.12
1.18mm	55 – 90	65.37
600 microns	35 – 59	49.43
300 microns	8 – 30	28.17
150 microns	0 – 10	7.21

Table 6. Mixture definitions based on IRC-44 and IS-383 [5,10]

Ingredient	Quantity
Cement	495 kg per m^3
Coarse Particles	1197 kg per m^3
Fine Particles	612 kg per m^3
Chemical Admixture	4.95 kg per m^3
Water	158.1 kg per m^3
Water-cement ratio	0.32

Mix Preparation

Ordinary Portland cement (OPC) as well as crushed granular blast furnace slag (CGBFS) employed as the mixture's binders. Cement and CGBFS had fineness of 360 and 870 m2/kg, respectively. At 3, 7, and 28 days, the strength activity index (SAI) for CGBFS was 1.64, 1.20, and 1.16, respectively. In previous concrete mixes, two single-sized coarse aggregates ranged from 5mm to 13mm or 13mm to 20mm.

The available through commercial, aggregate materials are either recycled concrete fragments or natural aggregate (granite). Natural aggregate has a specific gravity of 2.65, whereas recycled concrete aggregate had specific gravities of 2.19 and 2.04 for maximum sizes of 20 and 13 mm, respectively. In comparison to 1.0% for the original aggregate, the water absorption for 13mm as well as 20mm recycled aggregates from concrete mixes was 8.2% and 5.3% respectively.

As compared to 20 mm recycled aggregate, 13 mm recycled concrete aggregates seem to have a higher quantity of weakly bonded mortar, which results in lower specific gravity as well as higher water absorption [17]. To generate big open textured porous concrete, fine aggregate is purposefully left out of the mix formulations. To compress the concrete and help it settle in the mould, the mixture was first vibrated. A hydraulic conveyor is subsequently used to transport the compacted PIPB to the stackyard for air drying. The PIPB is water-cured for 24 hours after it has been air-dried. The stages typically taken in the casting of the PIPB are shown in Figure 2.

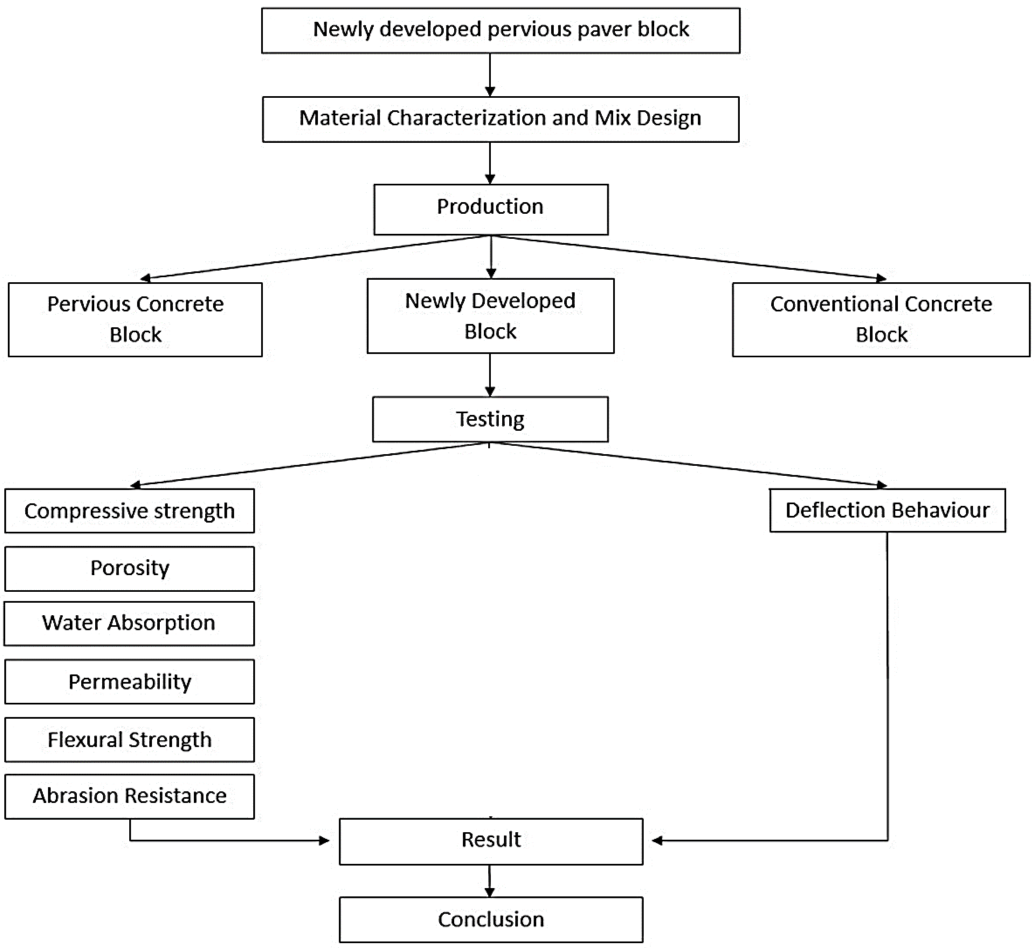

Figure 2. Experimental studies of various casted PIPBs [17].

In a typical pervious concrete mix, the binder material weighs 180–355 kg/m^3, the coarse aggregate weighs 1420–1600 kg/m^3, and the water to cement ratio ranges from 0.27 to 0.43. The normal vacancy ratios range from 14% to 31%, the typical strength of concrete after 28 days ranges from 5.6 to 21.0 MPa, and the typical coefficient of permeability ranges from 0.25 to 6.1 mm/s.

Design of Paver Block and Method of Preparing

To design the paver block IS 15658:2006 has been followed to decide the length and width and the depth has been kept as 80mm which is corresponding to the medium traffic conditions. The aspect ratio is kept less than 4 which also satisfy the IS 15658:2006 and yields 250/100=2.5 ≤ 4. This condition comes under the safe zones. Figure 3 shows the normal concrete block with pervious concrete.

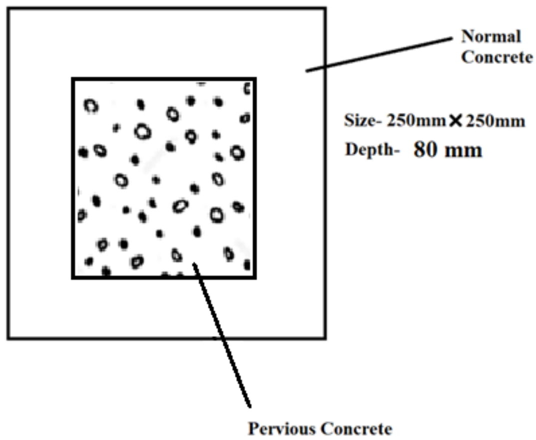

Figure 3. Normal concrete block with pervious concrete [15]

Test Methodology

The porosity, flexural strength, abrasion resistance, compressive strength and tensile properties of PIPB are evaluated after 7, 14 and 28 days curing. The testing process is conducted in accordance with IS15658:2006 [15]. For the 50mm of pervious paver block, a default value of 1.18 is used to estimate the mechanical strength properties.

Compressive Strength

Eight samples of each new design mix of paver block have been prepared to comply with the IS15658:2006 and then tested for compressive strength. The average of eight values is taken as apparent compressive strength The value of apparent compressive strength is then multiplied with the factor provided in Table 5 of Annexure D IS15658:2006 to get the result [18]. For deciding the grade of paver block Table 3 of IS15658:2006 is used.

Water Absorption

To analyze the water absorption test, tests have been performed on three samples and the methodology provided in Annexure C IS15658:2006 has been followed.

Porosity

Test performed as per procedure mentioned by 'Characterizing Enhanced Porosity Concrete using electrical impedance to predict acoustic and hydraulic performance' by Neithalath et.al.2006.

Permeability

A falling head permeability test apparatus has been constructed to ascertain the permeability of the newly developed paver blocks, employing the principles of the falling head test method. Four marks on the box at 1 cm, 6 cm, 11 cm, and another at 16 cm above the block has been made in the box. The internal dimensions of the hollow acrylic box have been intentionally made slightly larger than the paver. The inside boundaries of the hollowed acrylic blocks have been coated with silicone gel to guarantee that water would flow through the paver's internal pore framework in a one-dimensional fashion [19]. Glass putty has been used to fill up the tiny gaps between both pavers as well as acrylic boxes. A container has been put above an iron frame that supported the complete box assembly enclosing the specimens. Following steps have been followed to complete the test.

i. An iron frame along with an acrylic box is placed over the container.
ii. A paver block is placed inside the box.
iii. The gap between the paver and the box is closed with the help ofglass putty.
iv. Water is poured from the top until level slightly above the top marking (6 cm).
v. As the water level reaches the top mark start the stopwatch and note the time until it reaches the lower mark.
vi. By using the following formula, permeability has been calculated:

$$K = \frac{2.303\ A2 \times L}{A1 \times t} \log_{10}(h1/h2)$$

Where,

A1 = Area of pervious concrete portion (cm^2)
L= Thickness of paver (cm)
A2= Inner area (Space) of acrylic box (cm^2)
t= Time (secs)
H1= Upper-level mark (cm)
H2= Lower-level mark (cm)
K= Permeability (cm/sec)

Flexural Strength

The flexural strength of the specimen has been computed as per the procedure mentioned in the Annexure G 15658:2006. A total of eight samples of each design have been analyzed to complete the test.

Abrasion Resistance

Durability is a crucial component of PPB. The individual aggregates are held together by the cement paste to form a strong hexagonal lattice or honeycomb-like structure. It is crucial for the consistency of this framework that there be little material loss when exposed to abrasive force. One of the quick tests for determining the prepared mix's durability and stability is the Cantabro loss (CL) test. To conduct the test, the produced Paver block samples must be placed in the abrasion machine without the use of steel balls [20]. The machine rotates 300 times at a speed of 30 rotations per minute, as well as the percentage loss in Paver block weight is recorded as the Cantabro abrasion loss. In mathematics, it may be expressed as:

$$\text{Cantabro Loss (CL)}=(W_1-W_2)/W_1*100$$

Here, before the abrasion machine test, the PPB was compressed, and its weight is represented by W_1 and after the abrasion machine test, the specimen's weight is represented by W_2.

RESULT AND DISCUSSION

The strengths of pervious concrete mixes have been observed concerning the aggregate sizes, aggregate-to-cement ratio, water-to-cement ratio, as well as binder material type. Other sources have reported on the characteristics of pervious concrete with different mix ratios. The permeability has been 15mm/s for porous concrete that had a 10 MPa compressive strength. Pervious concrete shrinks less during the drying process than structural concrete.

Along with water penetration, pervious concrete also has other potential benefits, such as quick water drainage through the linked voids, which lessens wet weather spray and dims light. Water resources are conserved and groundwater is recharged because of water percolating through the porous concrete layer. Because of this, impermeable parking lots are thought to have a negative environmental impact [21]. Permeable surfaces in parking areas are thought to aid the encroachment and cleaning of stormwater.

Compressive strength

The compressive strength is tested for each block and 8 specimens have been utilized for this purpose. The exercise is performed as per the guidelines given in IS 15658:2006. A total of 8 samples have been used for the compressive strength testing for each block. Table 7 contains the data of compressive strength testing of paver block samples. The values of standard deviation as 1.01 to 1.96 indicated lesser variation in the value of compressive strength within the sample. This observation satisfies the criterion of 15658:2006 which states that the variation between the 8 specimens should be +15 % of average strength.

The function of normal concrete in newly developed paver blocks is to provide strength and that of pervious concrete is to provide permeability. So, as the portion of normal concrete increases the compressive strength of the block increases which is also reflected in the test result [22-24]. Table 8 gives the idea about the comparison of the strength of newly developed paver block and normal concrete (first column), pervious concrete (second column). NP50 and NP100 paver blocks almost have comparable strength when compared with normal concrete 79.6% and 71.59% strength reduction is less. Moreover, in comparison to the pervious concrete NP50, NP100 & NP150 have almost more than twice the increment in strength, which can increase their application.

Table 7. Compressive strength at different days [22-24]

PAVER ID	Compressive Strength (MPa)			Statistical Analysis of 28 Days Strength			
	7 Days	***14 Days***	***28 Days***	***No. of Samples***	***Mean***	***Variance***	***Standard Deviation***
NC	39.7	57.2	64.2	8	64.2	1.27	1.13
NP50	34.2	45.6	51.1	8	51.1	1.21	1.10
NP100	31.3	40.8	46.0	8	46.0	1.83	1.35
NP150	25.8	33.8	39.1	8	39.1	1.39	1.18
NP200	17.2	22.6	25.9	8	25.8	1.96	1.40
PC	12.5	15.6	18.6	8	18.6	1.01	1.00

Table 8. Comparison of compressive strengths [22-24]

Paver ID	Normal Concrete (%)	Pervious Concrete (%)
NP50	79.60	274.73
NP100	71.59	247.10
NP150	60.93	210.32
NP200	40.28	139.03

Porosity

Pervious concrete is having high porosity as compared to normal concrete due to the absence of fines (fine aggregate or sand). From the experimental result in Table 9, it can be seen that as the portion of pervious concrete increases, the porosity also increases. Moreover, all the newly created paver block compositions, except for NP50, yield porosities that are greater than the minimum allowable level of 15%, as specified by international bodies [1-2]. The results have also been supported by previous studies [25-27].

Table 9. Porosity analysis [1-2]

Paver ID	Porosity	Statistical analysis		
		Mean	***Variance***	***Standard deviation***
NP50	9.21	9.21	1.53	1.24
NP100	15.28	15.28	1.17	1.08
NP150	19.42	19.42	1.19	1.09
NP200	22.15	22.15	1.79	1.34

Water Absorption

To analyze the water absorption capability, IS:15658 2006 has been followed which suggests that the water absorption should be less than 6 %. It is observed in Table 10 that the selected pavers fulfilled the requirement of water absorption. The comparison of water absorption of the newly developed paver block with normal and pervious concrete is illustrated in Table 11. Data clearly shows that the water absorption in all new blocks has decreased by 23.07 % to 77.79 % as compared to that of pervious concrete. Decrement in the percentage of water absorption in the paver block is due to the lesser portion of pervious concrete which is highly prone to water absorption [28-29].

Table 10. Water absorption test [28-29]

Paver ID	Water absorption	Statistical analysis		
		Mean	**Variance**	**Std deviation**
NP50	1.42	1.42	1.06	1.03
NP100	2.49	1.61	1.12	1.06
NP150	4.31	2.49	1.27	1.13
NP200	5.37	2.87	1.38	1.18

Table 11. Water absorption comparison of normal and pervious concrete [28-29]

Paver ID	Normal Concrete (% increase in water absorption)	Pervious Concrete (% decrease in water absorption)
NP50	14.81	77.79
NP100	84.44	64.33
NP150	219.26	38.25
NP200	297.78	23.07

Permeability

Permeability is the main characteristics that make this newly developed paver block different from that of conventionally used paver blocks [30-32]. According to the IRC 58-2015 code, there is a minimum recommended permeability of 0.35 cm/s (equivalent to 300 m/day) for constructing a drainage layer in rigid pavements. It has been noted that as the proportion of pervious concrete increases, the permeability also increases. Further, the permeability of the paver block is directly related to the porosity of the paver block as porosity increases the value of permeability. In addition to that it is observed that there are many interconnecting voids present within the pervious concrete portion of the paver block which allows the water to drain easily and ultimately increases its permeability. From the experimental result, it can be deduced that every sample of the new block has satisfied the limit of permeability and the majority of samples have crossed the limit by almost more than twice which shows good permeability characteristics. The permeability test analysis for different Paver ID is given in Table 12.

Table 12. Permeability test analysis for different Paver ID [30-32]

Paver ID	Permeability (cm/sec)		
	6 cm - 1 cm	*11 cm - 1 cm*	*16 cm - 1 cm*
NP50	0.65	0.59	0.53
NP100	0.86	0.82	0.74
NP150	0.94	0.91	0.83
NP200	1.28	1.19	1.16

Flexural Strength (MPa)

The flexural strength is monitored as per the international quality standards for which the minimum suggested strength criteria for all blocks is 3.8 MPa (IRC: SP63,2018; EN1338,2003) and given in Table 13. All the sample blocks satisfy the above-specified limit except NP150 and NP200, which may be due to the large portion of pervious concrete which is quite weak in flexure. The results are given in Table 14. The comparison shows that flexural strength in NP50 is nearly equal to twice of pervious concrete and that of NP100 is 65.38 %. The results are also supported by previous studies [33-34].

Table 13. Flexural strength test results of the various samples [33-34]

PAVER ID	Flexural Strength (MPa)			Statistical Analysis of 28 Days Strength			
	7 Days	*14 Days*	*28 Days*	*No. of Sample*	*Mean*	*Variance*	*Standard Deviation*
NC	4.2	5.8	6.5	8	6.5	0.077	0.278
NP50	3.4	4.6	5.1	8	5.1	0.027	0.164
NP100	2.9	3.8	4.3	8	4.3	0.037	0.193
NP150	2.4	3.2	3.7	8	3.7	0.044	0.210
NP200	2.1	2.7	3.1	8	3.1	0.004	0.059
PC	1.8	2.2	2.6	8	2.6	0.085	0.292

Table 14. Comparison of FS increase in various concrete mixes [33-34]

Paver ID	Flexural Strength	% Increase in strength compared with pervious concrete
NP50	5.1	96.15
NP100	4.3	65.38
NP150	3.7	42.31
NP200	3.1	19.23

Abrasion Resistance

To assess the abrasion resistance during the results, it is observed that higher disintegration is observed in NP150 and NP200 samples. Although there is no specified limit of Cantabro loss while comparing the experimental values. The limit is designed for the abrasion value of aggregate which is used in cement concrete pavement in IRC:15-2011 and it should not be more than 35% as per the standard considerations. Overall, it can be observed that almost every sample of a block shows good abrasion resistance and also it can be due to the higher strength of concrete used in making the outer portion of the paver block [35-36]. These results can be observed in Table 15. Considering the strength criteria for medium traffic conditions corresponding to 44.125 MPa and all other criteria specified in Table 16, the NP100 paver block satisfied all the criteria and can be used as the pervious paver block in medium traffic conditions.

Table 15. Abrasion resistance test of concrete mixes [35-36]

Paver ID	Cantabro-Loss	Statistical analysis		
		Mean	Variance	Std deviation
NP50	24.17	24.17	8.78	2.96
NP100	32.21	32.21	3.36	1.83
NP150	41.29	41.29	0.93	0.97
NP200	50.12	50.12	1.96	1.40

Table 16. Comparison of various concrete mixes and tests to standards [35-36]

Experiment	NP50	NP100	NP150	NP200	Standard value
Compressive Strength	51.1	46	39.1	25.9	>44.125(M40 Grade paver block)
Porosity	9.21	15.28	19.42	22.15	>15%
Water Absorption	1.55	2.49	4.31	5.37	<6% (As per IS15658:2006)
Permeability	0.53	0.74	0.83	1.16	>0.35 (As per IRC 58:2015)
Flexural Strength	5.1	4.3	3.7	3.1	>3.8 (As per EN 1338, 2003;IRC:SP-63, 2018)
Abrasion Resistance	24.17	32.21	41.29	50.12	<35% (specified in point no 6)

Finite Element Analysis

FEA is used for numerically assessing the structural behavior of the pavement section built with a paver block [37-39]. Plaxis 3D software is used for simulating the load-deflection behavior of the pavement section when a normal or newly designed paver block is used. Two different models of dimension 1.015×1.015 m² are prepared one with normal concrete and another with a newly developed paver block (see Table 17). With the help of plaxis, 5mm deflection is given to the complete 1.015×1.015 m² surface and load deflection behavior is obtained and represented by Figure 4 and Figure 5. Based on the visualization, it is observed that the pavement cross-section is similar keeping the other conditions the same. Further, there are no changes in the load-deflection behavior of pavement that can justify the use of NP100 Paver block in medium traffic conditions.

Table 17. Load Deflection behavior [37-39]

Model-1		Model-2	
Load (kN)	***Deflection (mm)***	***Load (kN)***	***Deflection (mm)***
0.00	0.000	0.00	0.000
1.32	0.006	1.32	0.006
3.97	0.018	3.97	0.018
9.27	0.042	9.27	0.042
19.86	0.090	19.86	0.090
41.04	0.186	41.04	0.186
83.40	0.378	83.41	0.378
168.13	0.762	168.14	0.762
337.58	1.530	337.61	1.530
661.93	3.000	661.98	3.000

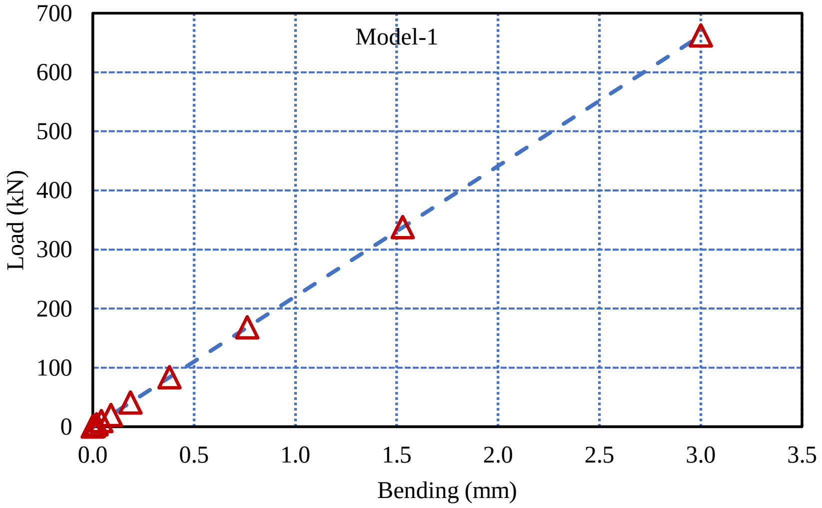

Figure 4. Load Bending behavior for Model-1 [37-39]

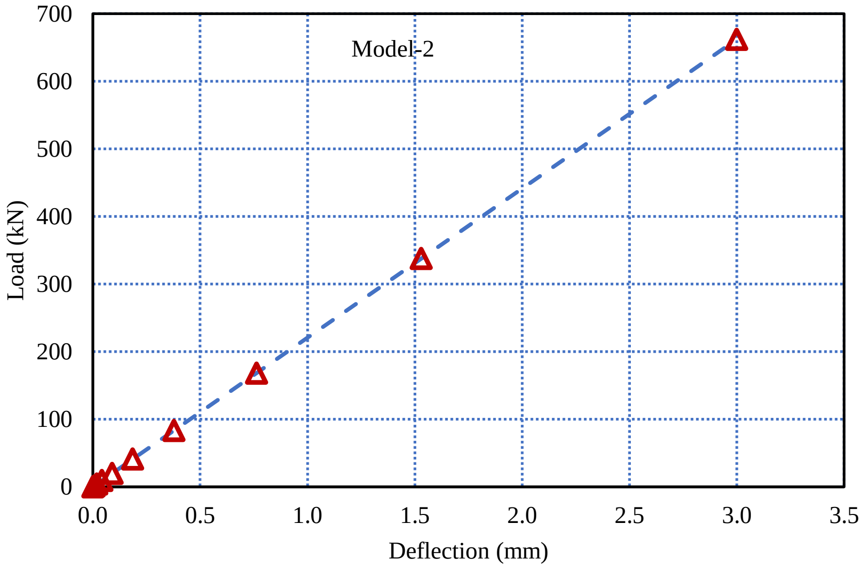

Figure 5. Load deflection behavior for Model-2 [37-39]

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The test findings showed also that the mix shows the necessary porosity, stronger shear strength, reduced deflection, as well as appropriate mechanical qualities. According to the current research, PIPB may be a useful pavement substance for low-traffic roads, noise reduction, pavements facing clogged drains, and urban heat islands [40],[41].

Control joints in concrete serve several important functions

- *Control of Cracking*: Concrete shrinks as it cures and dries, leading to the formation of cracks. Control joints are strategically placed to encourage cracks to occur along predetermined lines, controlling where the cracking happens and preventing unsightly random cracks.
- *Stress Relief:* By providing weakened planes, control joints help to relieve internal stresses within the concrete caused by temperature changes, drying shrinkage, and external loads.
- *Expansion and Contraction*: Concrete expands and contracts with changes in temperature. Control joints accommodate this movement, preventing the buildup of stress that could lead to cracking.
- *Maintenance:* Control joints facilitate easier maintenance of concrete surfaces. When cracks do occur, they tend to happen along these joints, making repairs simpler and less intrusive [42,43].

Typical infiltration rate for pervious concrete and compressive strength

- Pervious concrete's infiltration rate can change depending on a number of variables, including surface texture, aggregate size, compaction, and mix design. Pervious concrete, on the other hand, often absorbs between 2 and 18 inches of water per hour (or between 5 and 45 centimeters). Because of its high infiltration rate, pervious concrete is a good stormwater management option because it reduces runoff by allowing water to swiftly percolate through the surface and replenish groundwater [44].
- The compressive strengths of pervious concrete may range from around 500 psi (3.5 MPa) to 3000 psi (20.7 MPa) on average. However other formulations, particularly those aiming to increase porosity for improved water permeability, may have compressive strengths as low as 300 psi (2.1 MPa). In the end, variables like the intended usage, regional building rules, and technical specifications will determine the precise compressive strength needed for pervious concrete in a given application [45].

CONCLUSION

The goal of the study is to create an innovative interlocking pervious paver block and examine the mechanical characteristics and mechanical characteristics of PIPB pavement structures. The integration of polymers in the design of pervious concrete mix for paver blocks represents a significant advancement in construction technology. For the study, the variance in aggregate gradation as well as the proportion of penalties are considered. To determine the effectiveness of the concrete PIPB paver blocks, a series of mechanical as well as hydrological tests are performed as part of a research work. The elastic modulus is utilized as structural criterion to assess the longevity of paver blocks whereas hydrological research included the evaluation of both permeability and porosity. The findings demonstrated that when manufactured under controlled conditions, PIPB products address issues related to quality control and inherent lower tensile strength typically associated with traditional PCP designs, including weaker joints, edges, and corners. The mentioned PIPBs do not have a strong propensity for absorbing water, which points to their exceptional endurance. Additionally, these products have permeability and porosity rates that are equivalent to or greater than those of traditional PCP systems including PC paving blocks.

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