Permeable Pavements

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Abstract— Over the past few years cities and suburbs have become larger and densely populated, areas to be covered by vegetation has now been replaced by the Infrastructure, parking lots and walkways the absence of these natural surfaces has greatly disrupted the cycle of water the excessive use of impervious coverings has left cities with the challenge of managing increased run of volumes Bank erosion, Flooding and water clogging. Today these problems post consider of the risks to the sustainable development of cities and suburbs areas its a serious matter that require immediate attention and reliable solution. Permeable Pavements is a simple and lasting solution that imitates the original hydrological characteristic of soil its primary function allows runoff water pass through it directly into the ground being filtered by different layers of aggregate prior to returning it into the soil this helps reduce the volume of runoff rainwater that reduces the strain on the rainwater management system the reduced amount of volume helps to avoid overloads and flooding. It improves water quality and helps ground water recharge and also reduces the heat island effect and can be used where vegetation is not suitable. Permeable Pavements is a comprehensive resource for the proper design, construction and maintenance of permeable pavement systems that provide a transportation surface and a best management practice for storm water and urban runoff. A cornerstone for low impact development (LID) and sustainable site design, permeable pavements are considered a green infrastructure practice. They offer many environmental benefits, from reduced storm water runoff and improved water quality to better site design and enhanced safety of paved surfaces. Commonly used for walkways, driveways, patios, and low-volume roadways as well as recreational areas, parking lots, and plazas, permeable pavements are appropriate for many different land uses, particularly in highly urbanized locations. This volume synthesizes today's knowledge of the technology, drawing from academia, industry, and the engineering and science communities. It presents an overview of typical permeable pavement systems and reviews the design considerations. Detailed design, construction, use, and performance information is provided for porous asphalt, pervious concrete, permeable interlocking concrete pavement, and grid pavements. Fact sheets and checklists help to successfully incorporate permeable pavement systems into design projects. Additional chapters summarize emerging technologies, maintenance considerations, hydrologic design approaches, key components for specification writing, and key areas for additional research. Appendixes include a fact sheet clarifying information on common concerns, as well as data tables summarizing water quality treatment performance and costs. Permeable pavements is an essential reference for engineers, planners, landscape architects, municipalities, transportation agencies, regulatory agencies, and property owners planning to implement this best management practice for stormwater and urban runoff.

Keywords: Permeable Pavements, Rain water runoff, Rain Water Harvesting

I. INTRODUCTION

Permeable pavements are alternative paving surfaces that allow storm water runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including pervious concrete, pervious asphalt and permeable interlocking concrete pavers. While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom..Different types of layer shown in fig 1,

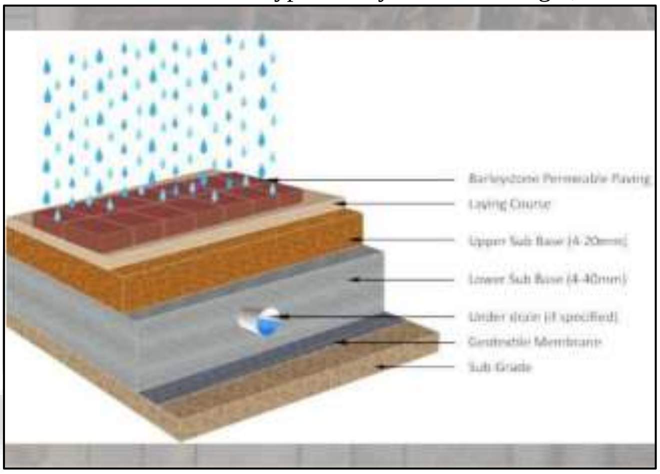

Fig. 1: Different types of layer

A. Features

Permeable pavements offer many benefits, both aesthetic and practical.

- Reduces stormwater runoff, including reduction of temperature, total water volume, and flow rate
- Treats water runoff
- Increases groundwater infiltration and recharge
- Provides local flood control
- Improves the quality of local surface waterways
- Reduces soil erosion
- Reduces the need for traditional stormwater infrastructure, which may reduce the overall project cost
- Increases traction when wet
- Reduces splash-up in trafficked areas
- Extends the life of paved area in cold climates due to less cracking and buckling from the freeze-thaw cycle
- Reduces the need for salt and sand use during the winter, due to little or no black ice
- Requires less snow-plowing
- Reduces groundwater pollution
- Creates green space (grass groundcover, shade from tree canopies, etc.)

B. Advantages

– Managing runoff

Permeable paving surfaces have been demonstrated as effective in managing runoff from paved surfaces. Large volumes of urban runoff causes serious erosion and siltation in surface water bodies. Permeable pavers provide a solid ground surface, strong enough to take heavy loads, like large vehicles, while at the same time they allow water to filter through the surface and reach the underlying soils, mimicking natural ground absorption. They can reduce downstream flooding and stream bank erosion, and maintain base flows in rivers to keep ecosystems self-sustaining. Permeable pavers also combat erosion that occurs when grass is dry or dead, by replacing grassed areas in suburban and residential environments.

– Controlling pollutants

Permeable paving surfaces keep the pollutants in place in the soil or other material underlying the roadway, and allow water seepage to groundwater recharge while preventing the stream erosion problems. They capture the heavy metals that fall on them, preventing them from washing downstream and accumulating inadvertently in the environment. In the void spaces, naturally occurring micro-organisms digest car oils, leaving little but carbon dioxide and water. Rainwater infiltration is usually less than that of an impervious pavement with a separate stormwater management facility somewhere downstream. in areas where infiltration is not possible due to unsuitable soil conditions permeable pavements are used in the attenuation mode where water is retained in the pavement and slowly released to surface water systems between storm events.

– Trees

Permeable pavements may give urban trees the rooting space they need to grow to full size. A structural-soil pavement base combines structural aggregate with soil; a porous surface admits vital air and water to the rooting zone. This integrates healthy ecology and thriving cities, with the living tree canopy above, the city's traffic on the ground, and living tree roots below. The benefits of permeable on urban tree growth have not been conclusively demonstrated and many researchers have observed tree growth is not increased if construction practices compact materials before permeable pavements are installed.

II. Pavement Material:

Pavement Material In the present study, the design considerations for concrete incorporating recycled plastics to be used in a permeable interlocking pavement system are based on the following requirements:

- Canadian Standards Association CSA–A231.2 requires that the blocks used in interlocking concrete pavements must have a minimum average compressive strength of 40 MPa at delivery.
- ASTM C936 requires that the average water absorption to be no greater than 5%. From an earlier publication by Wong, an optimum mix (P3) containing 25% polystyrene PS (by volume of total aggregates) recorded a 28-day compressive strength of 45.50 MPa, which fulfilled the minimum compressive strength requirement of 40 MPa at delivery. Mix P3 also had average water absorption of 0.50%, which was in compliance with the maximum water absorption requirement of 5%.
- The higher water absorption of spherical low-density polyethylene (LDPE) bead of 1-5 mm made it ideal to be used in the sand bedding course; whereas larger-sized high-density polyethylene (HDPE) of 1-50 mm and polypropylene (PP) of 1-30 mm with high water absorption are suitable for the gravel base material.

A. Prototype Material:

The prototype in this project adopted the following materials, as illustrated in Fig. 2.

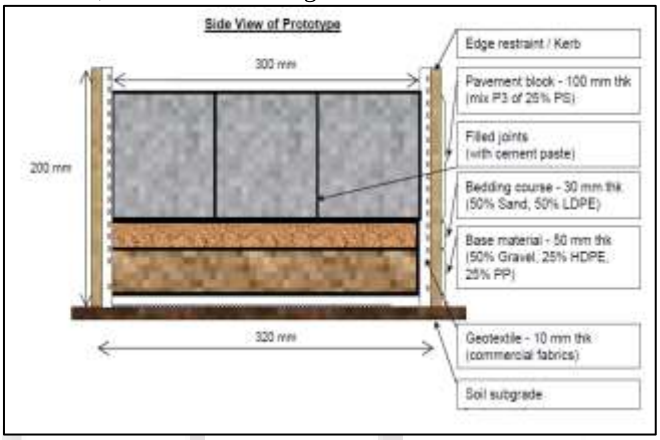

Fig. 2: prototype of permeable interlocking pavement system

- Edge restraint / Kerb: an edge restraint or a kerb was placed before laying the base material and the bedding course. · Pavement block: made from optimum mix P3 containing 25% PS (by volume).
- Filled joints: The joints of 5-mm gap between the pavement blocks were filled with cement paste (these filled joints provided structural strength to the pavement system, yet allowing water to infiltrate to the bedding course).
- Bedding course: 50% Sand, 50% LDPE (by volume) which allowed water to permeate through to the base material.
- Base material: 50% Gravel, 25% HDPE, 25% PP (by volume) which allowed water to infiltrate to the geotextile and soil sub grade
- Geotextile: Made of commercially available fabrics to support and strengthen the soil subgrade, yet permitting water to flow through from the filled joints, bedding course and base material to the soil subgrade.
- Soil Subgrade: Good drainage of the subgrade (drainage of rainwater and groundwater) would benefit the behaviour of the pavement.

B. Construction of prototype:

The following procedure was adopted in this study to construct the prototype of a permeable interlocking pavement system:

Fig. 3- (a): Laying of geotextile after constructing the edge restraints and preparing (e.g. excavating, compacting) the soil sub grade below.

Fig. 3- (b): Spreading and compacting the base material (50% gravel, 25% HDPE, and 25% PP).
Fig. 3- (c): Placing and compacting the bedding course (50% sand and 50% LDPE).
Fig. 3- (d): Placing the concrete pavement blocks (using mix P3 containing 25% PS) and filling the joints with cement paste

Fig. 3: Construction of the prototype of a permeable interlocking pavement system

C. *Pavement Surface Design:*

Permeable pavement surface materials and installation shall be in accordance with industry standards for their intended use:

– Pervious Concrete - Comply with American Concrete Institute Specification for Pervious Concrete Pavement or recommendations of the Wisconsin or National Ready Mixed Concrete Associations.
– Pervious Asphalt - Comply with recommendations of the Wisconsin, or National Asphalt Pavement Associations.
– Permeable Pavers/Blocks – Comply with recommendations published by the Interlocking Concrete Pavement Institute, Brick Industry Association or National Concrete Masonry Association.
– Other Pavement Surfaces – For permeable pavement surfaces that are not specifically mentioned in this technical standard, comply with the appropriate industry standards or recommendations.

Fig.3: Pervious pavement using interlocking pavers

III. Operations and Maintenance:

1) An operation and maintenance plan shall be written for the intended life of the permeable pavement system. The plan shall include an inspection checklist and schedule.

2) The following activities shall be prohibited from occurring on the permeable pavement surface

– Temporary or permanent stockpiling of soil or other material that can potentially cause or contribute to clogging.
– Application of pavement seal-coating.
– Application of sand for dicing.

3) Inspection of the permeable pavement system shall be conducted at least once per year to evaluate the following:

Pavement Condition – Inspect permeable pavement surfaces for settlement, deformation or cracking.
Surface Infiltration – Inspect permeable pavement surfaces f or sedimentation or evidence of ponding.
Drainage – Inspect observation wells72 hours after a rain event of 0.5inches or greater to verify that the aggregate storage reservoir is draining down effectively.
Outfalls - Inspect under drain outfall locations for obstructions and erosion.
Run-on Areas – Inspect run-on areas for adequate cover and stability.

4) Maintenance of the permeable pavement system shall be conducted as follows:

– Clean the pavement surface using industry recommended methods, such as regenerative air or vacuum sweeping, at least twice per year in accordance with Section V.G.
– If water ponding persists on the pavement surface after a storm event, clean the pavement surface to mitigate clogging.
– Repair any settlement, deformations or cracking that are significant enough to adversely impact the water quality function of the system.
– Repair blocked, restricted or eroding under drain outfalls.
– Repair and/or replant eroding run-on areas.
– For permeable pavers/blocks with joints that are filled with aggregate in accordance with industry recommendations.
– If necessary, remediate the system by extracting accumulated debris and aggregate from the joints using a vacuum and re-filling the joints with new aggregate.
– For porous asphalt and pervious concrete, repair may be done with conventional impervious materials. If the total impervious repair areas do not exceed 10% of the original permeable surface area and runoff from the repair areas will run on to the adjacent permeable areas. The 10% threshold may only be exceeded if design calculations confirm that the system is still able to accept the full loading for which it was originally designed.

5) If the pavement surface infiltration rate is questionable at any time during the effective life of the pavement, the administering authority may require infiltration rate testing to verify that the surface infiltration rate is no lower than10 in/hr. If the surface infiltration rate is lower than 10 in/hr, appropriate action shall be taken to restore the infiltration *rate to an acceptable level based on the remaining effective life of the pavement. 3.1.6 If verification of in place pavement surface infiltration rates is necessary, conduct pavement surface infiltration rate testing per ASTM C1701 Standard Test Method for Infiltration Rate of In Place Pervious Concrete for pervious concrete and pervious asphalt, ASTM C1781 Standard Test Method of Surface Infiltration Rate of Permeable Unit Pavement Systems for permeable pavers/blocks or other methods approved by the administering authority.*

- All inspection, infiltration testing and maintenance activities shall be documented in written reports. -- All written reports shall be made available on request by the administering authority.
- Qualified personnel, as determined by the administering authority, shall perform inspection, infiltration testing and maintenance work.

IV. PAVEMENT PATTERN:

Herringbone pattern versus stretcher pattern According to the Interlocking Concrete Pavement Institute ICPI, the most effective laying patterns for maintaining interlock is the herringbone pattern (Fig. 4). This pattern offers greater structure capacity and resistance to lateral movement than other laying patterns, e.g. the stretcher pattern in. Fig. 4-b-a).

Shackel and Lim reported that during construction and under traffic loading, pavement blocks progressively wedge together and develop interlock. For the case of stretcher pattern

(Fig. 4-a-b), if pavement block B is subjected to rotation (represented by the curved arrow) about a horizontal axis, it is free to slide along pavement blocks A and C. Pavement block B will only push on the blocks (e.g. pavement block D) in line with the rotation. Hence, the wedging action occurs only in the direction shown by the straight arrows in Fig. 4-e-b.

In the case of herringbone pattern (Fig. 4-e-a),while the rotation (denoted by the curved arrow) of pavement block B can still occur without horizontally displacing blocks A and C, the movement of block B about a horizontal axis will now induce some rotation of block D about the vertical axis. This is in addition to developing horizontal wedging as shown by the straight arrows in . Fig. 4 b, This tends to increase the wedging and thus interlocking action throughout the pavement surface, and explains why herringbone pattern performs better than stretcher pattern. Based on the above discussion, herringbone pattern was chosen over stretcher pattern to lay the pavement blocks for the development of the prototype.

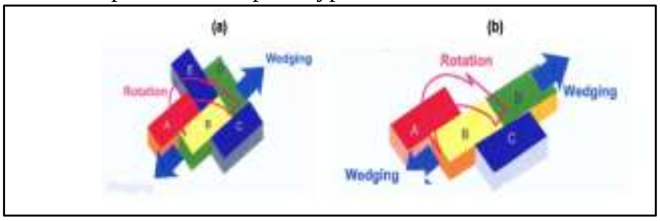

Fig. 4: Effects of rotation on the wedging action in (1) herringbone and (2) stretcher patterns

V. TESTING

A. Aggregate testing:

Aggregate testing is use for measure quality of aggregate.

B. Water absorption test:

Water absorption test is used for determining the absorption of water by the aggregate ashown in table 1

C. Specific gravity test:

It is used for determining the density of aggregate with respect to water at same volume results shown in table no.2.

D. Aggregate impact value test:

This test is used for find the toughness of aggregate result shown in table no 3.

S. No.	Determination No.	Sample I	Sample II	Sample III
1	Weight of saturated surface – dried sample in gm (A)	2409	2380	2491
2	Weight of oven-dried sample in gm (B)	2404	2375	2486
3	Water absorption =A-B*100% B	2409-2400*100=0.21% 2404	2380-2375*100=0.21% 2375	5 *100=0.21% 2486
Average water absorption value				0.206%

Table 1: water absorption of course aggregates

S. No.	Description	Sample I	Sample II	Sample III
1	Weight of the oven dry sample in air (gm)A	490.2	484.5	487
2	Water of sample in water (gm)B	301.5	300.5	303
3	Weight of saturated surface dry sample (gm)C	492	486.5	488
4	Specific Gravity=A/(C-B)	2.573	2.604	2.632
5	Water absorption (%)=100*(C-A)/A	0.367	0.412	0.205
Average specific Gravity=			2.603	
Average water absorption =			0.328	

Table 2: Specific Gravity fine aggregate test results

S. No.	Determination No.	Sample (gms)
1	Sample mould weight (W1)	2539.4
2	Sample mould weight and sample weight (W2)	3057.3
3	Sample weight before blows(W3)	3057.3-2539.4=517.8

4	Crush sample weight(M1)	517.2
5	sample weight passing sieve2.36mm (M2)	81.8
6	Sample weight retained in sieve 2.36mm (M2)	435.2
7	The aggregate impact value AIV= M2*100 M1	AIV=81.8*100=15.82% 517.2

Table 3: impact value of aggregate

VI. PAVEMENT TYPE:

Permeable pavements versus conventional impermeable pavements

The Interlocking Concrete Pavement Institute reported the following advantages of permeable pavements as compared to conventional impermeable pavements:

– Permeable pavements manage storm-water runoff more efficiently than conventional impermeable pavements by limiting runoff volume and relieving flooding in storm sewers.
– Permeable pavements filter and treat storm-water runoff more effectively than conventional impermeable pavements through the filtering action of the bedding course and base material which reduces total suspended solids, phosphorus and other water pollutants in the runoff.
– Permeable pavements meet the sustainable requirement to reduce "urban heat islands", which is the thermal difference between urban and rural areas. These pavements are cooler (due to higher reflectivity of sunlight from the surface) than conventional impermeable pavements, thereby minimizing impacts on the microclimates and wildlife habitats. Based on the above discussion, permeable pavement system was chosen over the conventional impermeable pavement for the development of the prototype. fig.no 5
– Showing different types of permeable pavment.

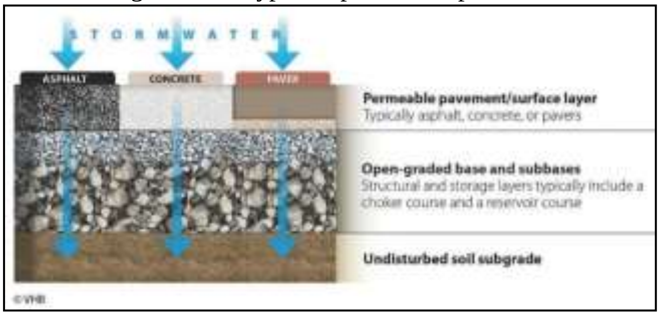

Fig. 5: Types of Permeable Pavements

VII. IMPLEMENTATION

In India roads in most of the cities become deadly every year after monsoon due to improper drainage system, excessive use of impervious coverings causes Flooding and water clogging. After every heavy rain of the season cities came to a standstill. Waterlogged roads, choked drains, traffic snarl,(fig no 6) cancelled/delayed trains and flights and left cities with the challenge of managing increased run of volumes Flooding and water clogging and it becomes almost impossible to travel in this condition Permeable pavement systems that provide a transportation surface and a best management practice for storm water and urban runoff we can use permeable pavement instead of conventional impermeable pavements in sidewalks, parking lots and where vegetation in not convenient. Permeable pavement systems are an alternative to other pavements and storm water control measures in areas where mitigating the adverse impacts of storm water discharges is an objective or requirement. Permeable pavement systems are most effective in areas where subsoil and groundwater conditions are suitable for storm water infiltration, and the risk for groundwater contamination is minimized.

Fig. 6: Traffic condition during rainfall

VIII. CONCLUSION

India, being on the verge of becoming a developed country needs to channel its efforts that sustain its development process. This paper looked at various studies conducted on permeable pavement systems and their current application. Also discussed about the design of permeable pavement in brief. Maintenance and water quality control aspects relevant to the practitioner were outlined for permeable pavement systems. The recent innovations like development of a combined geothermal heating and cooling, These permeable pavement systems are changing the way human development interacts with the natural environment. Its application towards parking lots, highways and even airport runways are all improvements in terms of water quality and safety.

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