Permeable Pavements: New Technique For Construction Of Road Pavements in India

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Abstract - *The purpose of this paper is to summarize literature on permeable pavements, highlight current trends in research and industry, and to recommend future areas of research and development. Permeable paving is a range of sustainable materials and techniques for permeable pavements with a base and sub base that allow the movement of storm water through the surface. In addition to reducing runoff, this effectively traps suspended solids and filters pollutants from the water. The goal is to control storm water at the source, reduce runoff, reduce cost and improve water quality by filtering pollutants in the substrata layers and increase subsurface water level, thus one way to harvest storm water. In Maharashtra, fly ash is generated in huge quantity in thermal power stations. The disposal of fly ash is also a major socio-economic problem. So the use of fly ash up to 10-30% as a replacement to a cement can overcome this problem. The use of fly ash will reduces the construction cost and also solve disposal problem. Porous pavement is unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, this pavement technology creates more efficient land use by eliminating the need for retention ponds, swell, and other costly storm water management devices.*

Key Words: **Permeable pavement, Sustainable material, Storm water, Filters pollutants, Environmental benefits, Cost, Retention ponds.**

1.INTRODUCTION

Impervious surfaces have mostly used in the decline of watershed integrity in urban and urbanizing areas. These surfaces are mostly used to serve vehicle travel, but a maximum portion of these surfaces, particularly driveways, parking lots and road shoulders, experience only minimal traffic loading. Parking lots are of sized to accommodate maximum traffic usage, which only occurs occasionally, so most of the area remains unused during majority of the time. The large impervious surfaces leads to higher peak stream flows which cause bank erosion, increased sediment transportation, reduction in infiltration which reduces groundwater recharge and lowers stream base flow. Runoff from impervious surfaces also increases pollutant quantity in surface flow.

Permeable pavement is a best solution for problem of increased storm water runoff and decreased stream water quality. Permeable pavements are an emerging technology constructed for low volume roads and parking lots as an alternative storm water management technique or best management practice. Permeable pavements are alternative paving surfaces that capture and temporarily store the storm water by filtering runoff through voids in the pavement surface into an underlying stone reservoir. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially infiltrate into the soil. This system is not so widely used in India.

Permeable Pavement Systems are designed to achieve water quality and quantity benefits by allowing movement of storm water through the pavement surface and into a base/sub base reservoir. The water passes through the voids in the pavement materials and provides the structural support as conventional pavement. That's why permeable pavements can be served as an alternative to conventional road and parking lots. These pavements have ability to reduce urban runoff and trap pollutants. Also it provides the opportunities to reduce the impacts of urbanization on receiving water systems by providing at source treatment and management of storm water. Permeable pavement systems have been shown to improve the storm water quality by reducing the pollutant concentrations and pollutant loading of suspended solids, heavy metals, hydrocarbons and some nutrients.

2. PERMEABLE PAVEMENT SYSTEMS

2.1 Applications

Permeable pavement systems are suitable for wide variety of applications like commercial, residential, industrial, yet for light duty and less usage, even though this systems can be used for much wider range of usage. The areas where there is possible mitigation of pollutant in the groundwater, permeable pavement should be constructed and infiltrated water should be discharged into a suitable drainage system. General applications of permeable pavement systems are as follows:

- For residential driveways, roadway shoulders, service and access driveways
- Parking areas
- Bicycle paths, Jogging paths
- Erosion control and slope stabilization
- Land irrigation
- Cart paths and Parking of Golf course
- Tennis Court

2.2 Types of Permeable Pavements

Fig – 1 Types of permeable pavement

Numerous types of permeable pavement are available. Pervious concrete is most common today, but porous asphalt, interlocking concrete pavers, concrete grid pavers, and plastic reinforced grids filled with either gravel or grass are also available. Other types and variations exist, but these are the most popular and versatile designs. The pavement type itself typically refers only to the surface layer of a structure consisting of multiple layers. To prevent clogging, only cleaned, washed stone that meets municipal roadway standards should be used. Depending on design needs, perforated pipes can be added near the top of the stone reservoir to discharge excess storm water from large events. Also, instead of allowing storm water to infiltrate into the underlying soil or where the permeability of the underlying soil is not optimal, perforated under drain pipes can be installed to route water to an outflow facility structure. It is recommended that an observation well to be installed at the down-gradient end of the permeable pavement to monitor performance.

2.2.1 Porous asphalt :-

Porous asphalt is a standard asphalt mixture of both fine and coarse aggregate bound together by a bituminous binder except it uses less fine aggregate than conventional asphalt. The void space in porous asphalt is similar to the 15 to 35 percent of pervious concrete. The surface appearance of porous asphalt is similar to conventional asphalt, though porous asphalt has a rougher texture. The surface layer of asphalt is usually thinner than a comparable installation of pervious concrete. While the compressive strength of pervious concrete is usually less than that of conventional concrete, the compressive strength of porous asphalt is comparable to that of conventional asphalt. Porous asphalt can be used for pedestrian applications such as greenways and low volume, low speed vehicular traffic applications such as parking lots, curbside parking lanes on roads, and residential or side streets

2.2.2 Pervious concrete :-

Pervious concrete is a mixture of Portland cement, coarse aggregate or gravel, and water. Unlike conventional concrete, pervious concrete contains a void content of 15 to 35 percent (average of 20 percent) that is achieved by eliminating the finer particles such as sand from the concrete mixture. This empty space allows water to infiltrate the underlying soil instead of either pooling on the surface or being discharged as runoff. Sidewalks and parking lots are ideal applications for pervious concrete. The structural strength of pervious concrete, although typically less than standard concrete mix designs, can easily withstand the relatively light loads generated by pedestrian and bicycle traffic. The loads placed on pervious concrete in parking lots can be much more substantial and require consideration when selecting the concrete mix and pavement thickness. While the structural strength of porous concrete can be increased by adding larger amounts of cement, the porosity will decrease, thus decreasing infiltration rates.

2.2.3 Pavers :-

Permeable interlocking concrete pavers (PICP) and clay brick pavers (PICBP) as well as concrete grid pavers (CGP) are similar in installation and function but are made from different materials. PICPs are solid concrete blocks that fit together to form a pattern with small aggregate-filled spaces in between the pavers that allow storm water to infiltrate. These spaces typically account for 5 to 15 percent of the surface area. PICBP as the same as PICPs except the material is brick instead of concrete. With CGPs, large openings or apertures are created by the CGPs lattice-style configuration. These openings, which can account for 20 to 50 percent of the surface area, usually contain soil or grass, though small aggregates can be used. While CGPs have larger openings than PICPs and PICBPs, they are not designed for use with a stone reservoir but instead can be placed directly on the soil or an aggregate base. As such, the infiltration rate of PICPs and PICBPs is much higher than that of CGPs. Plastic turf reinforcing grids (PTRG) are made of interlocking plastic units with large open spaces. PTRG are generally used to add structural strength to topsoil and reduce compaction.

2.3 Need Of Permeable Pavement

- To solve traffic jam problems in highly developed areas due to problem of water logging.
- To reduce the imbalance in natural ecosystem.
- By using permeable paving system, we can collect the rainwater/ Storm water by this system and store to ground water table or by constructing a tank.

- Permeable pavement can reduce the concentration of some pollutants either physically (by trapping it in pavement or soil), chemically (bacteria and other micro-organisms can breakdown and utilize some pollutants), or biologically(plants that grow in some types of pavements).

2.4 Life Span

The life span of porous pavement is mainly depends upon the size of air voids in the media. Due to more voids, there is more possibility of oxidation, so durability is less. It can be expected that the life span of permeable pavement is shorter than the impermeable pavements due to oxidation, subsequent stripping, deterioration by runoff and air infiltration.

2.5 Quality of Water

2.5.1 Pollutant

Permeable pavements are good in removing suspended solids and nitrogen. When an under drain system is provided into the pavement system, storm water is infiltrated and collected into the under drain, where nitrogen can be removed by plant uptake or denitrified.

Along with atmospheric pollutants, harmful pollutant can also be emitted from road surfaces and roof material. Copper, hydrocarbons and lead show the highest pollutant concentration. Metal roof if not cleaned prior to discharge, usually show high concentrations of heavy metal in the corresponding runoff.

2.5.2 Metals

Studies have shown that the water quality is improving by filtration through permeable pavement systems, which work well in removing heavy metals and suspended solids from runoff. In comparison to pavements made of asphalt, concentration of copper, lead and zinc were significantly lower on permeable pavements. Generally permeable pavements are effective in trapping heavy metals in surface runoff. However, not all pavers have ability to trap dissolved heavy metals. The joint filling material for pavements with large joints should be such that it should not allow metals to pass through it. If so it may enter in groundwater resources.

2.5.3 Hydrocarbons

Diesel and oil fuel residue is frequently detected on non-permeable surfaces. In comparison, these were not detected on permeable pavements. If hydrocarbons are not removed in sufficient quantity during infiltration through surface layer it may endanger soil and groundwater. Many pollutants such as polycyclic aromatic hydrocarbon, phosphorous, metals and organic compounds are absorbed onto suspended solids. Models have been designed to estimate the suspended solids load during rainfall events, leading to better understanding of receiving waters being polluted by hydrocarbons. Wilson incorporated an oil interceptor into a permeable surface construction. Tests were carried out for the worst possible rainfall event and pollution to assess how the system retains pollutants within its structure. The results from this successfully says that this system can retain hydrocarbons and can offer outflow of better water quality. However, where certain detergents are present in the pavement system, they may contaminate the water, which may be require secondary treatment to improve its water quality.

3. RELATED WORKS

A sustainable drainage system is designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharges. The term sustainable urban drainage system is not the accepted name, the 'Urban' reference having been removed so as to accommodate rural sustainable water management practices.

AASHTO Guide for Design of Pavement Structures[1] provides a comprehensive set of procedures which can be used for the design and rehabilitation of pavement; both rigid and flexible and aggregate surfaced for low volume roads. The guide has been developed to provide recommendation regarding the determination of the pavement structures. The procedure for design provide for the determination of alternate structure using a variety of material and construction procedures. Beeldens A et.al.[2] stated that To ensure the combination of the bearing capacity and the water storage of the pavement, a special design is applied where both parameters are assigned respectively to the base and the sub base layer. In her paper describes various thickness to be adopted under different foundations. She also determined the thickness based under different loading conditions. Benjamin O.[3] evaluated the performance of four permeable pavement systems with respect to durability, infiltration and water quality after 6 years of daily use. All four permeable pavement systems showed no major signs of wear. All rainwater infiltrated through these systems, with almost no surface runoff. Their study stated that water quality of infiltration is better than the surface runoff from the asphalt parking area. For all systems copper, zinc concentrations are below toxic level. Motor oil was detected in 89% of samples from asphalt runoff but was much lower in infiltration. E. Z. Bean et.al.[4] studied the infiltration rate of permeable pavements. Asphalt surfaces have greatly increased the amount of pollutant-carrying runoff entering surface waters. To overcome this, permeable pavement can be installed to allow water to infiltrate, thus reducing runoff and acting as filter. They conclude that maintenance using a vacuum sweeper should be performed once in a year for CGP sites filled with sand. Removing top 1.3 cm layer of material accumulated in void spaces improve the infiltration rates. Also PICP lots should be sited away from the areas with free fine particles. Fine particles have been shown to severely decrease infiltration rates. Chai, L., Kayhanian et.al.[5] regarding pollutant removal efficiency, permeable pavement has been consistently shown to be capable of removing 80-95% of total suspended solids (TSS) from stormwater. Unlike TSS removal, the removal rate of total phosphorus (TP) has varied widely in previous studies. Several study observed that the removal rate of TP is greater than 70%, whereas other works documented low TP removal rates ranging from 40% to 60%., however, he also claimed that permeable pavement barely removes TP from stormwater runoff. In addition, water quality performance of PC is also a function of its engineering structure (i.e., the thickness of gravel layers and gravel size), in addition to climatic and geographic conditions. Few studies have been conducted to assess the effects of gravel size and the depth of gravel layers on pollutant removal.And demonstrated a link between the capability of removing TSS and TP and the depth of the gravel layer consisting of 10.5 mm gravels, which are typically used in the bedding layer of permeable pavements.

4. FUTURE RESEARCH

Till date, the application of permeable pavement has been limited to some specific applications like parking lots, low volume roads. Future research may allow for new and innovative applications such as village roads, airport runways. Permeable pavements generally have low strength but by increasing its strength and improving the properties it can be used for construction heavy traffic roads like Urban roads, Highway Shoulders, etc. Generally in densely populated area less land space exists. So that roads are not properly arranged and also surface drainage facilities are not provided properly. So in rainy seasons the problems of water clogging arises. So For these areas permeable pavement can become a good option. In parks or gardens jogging tracks or walkways are mainly constructed of compacted soils. But in rainy seasons these roads becomes muddy which cannot be used for their intended purpose. This causes various problems to pedestrians. So for this type of situations permeable pavements can be proven advantageous.

Future research on effects of contaminants that remain in permeable pavement system should be taken under consideration. Also the impact of this system on environment after long time are unclear. Before all of this research has to be done to improve the lifespan of system as well as to reduce the cost of permeable pavement. If these problems were solved this system can be installed in more places in India.

5. CONCLUSION

This paper describes about the permeable pavements, its types, needs and its present applications. This paper also looked at various literature and studies conducted on permeable pavement systems. The water quality and life span aspects were outlined for permeable pavement systems. Types of contaminant present in the water and which are removed in this system are explained here. Future research and scope of this system is discussed in this paper briefly. The permeable pavement systems are changing the way of human development with natural environment. Its applications towards highways, road shoulders, parking lots and airport runways in India are all improvements in terms of water quantity, water quality and safety.

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