IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 5 ISSUE : 3 Print / Issue Publication Date: 15-Sep-2020

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2020.v05i03.040

Indexed In

Google SCHOLAR OPEN ACCESS doi Crossref

WWW.IJEAST.COM

editor@ijeast.com

International Journal of Engineering Applied Sciences and Technology, 2020
Vol. 5, Issue 3, ISSN No. 2455-2143, Pages 255-260
Published Online July 2020 in IJEAST (http://www.ijeast.com)

A SUSTAINABLE APPROACH FOR URBAN FLOOD MITIGATION USING PERMEABLE PAVEMENT SYSTEMS: A REVIEW

Suman Markuna
M.Tech, SWCE, College of Technology,
GBPUAT Pantnagar, Uttarakhand, India

Divyanshu Bhatt
M.Tech, SWCE, College of Technology,
GBPUAT Pantnagar, Uttarakhand, India

Abstract- **This paper reviews the mitigation of urban flood by using Permeable pavement systems in different countries in the world. In India, many states which are well developed such as Maharashtra, Delhi, Karnataka, Gujarat, Tamil Nadu, Madhya Pradesh suffers from the urban flood from the last few decades. There are various techniques have been used to mitigate the urban flood risk but this paper concludes the review for mitigation of urban flood by using permeable pavement systems such as porous asphalt pavements, pervious concrete pavements, plastic grid pavers, permeable interlocking concrete pavement, and fully permeable pavement. Urban flooding is different than rural flooding because of urbanization. Permeable pavers are very useful in cities since porous pavements reduce the effect of urban stormwater and both serve as the best pavement according to BMP's use. The construction of the permeable pavement depends on many factors that should be considered before construction and can be provided in parking lots, lawns, roofs, parks, walkways (industries, institutions, hospitals, shopping malls, etc), the footpath of colonies or building area, etc. The surface runoff water can be stored temporarily in pavement systems and further filtered and can be used in non-potable, irrigate the flowers, cleaning of vehicles, etc.**

Keywords- **Urbanization, imperviousness, urban flood, permeable pavement systems**

I. INTRODUCTION

With the increasing development of urbanization, it results in impervious areas because development in urbanization takes place road connectivity, roofs, industrial areas, parking lots, hospitals, restaurants, parks, buildings, institutes, etc. Which introduce in a reduction of land which naturally absorbs the amount of precipitation and removal of vegetation from the surfaces. By which the infiltration of rainfall in urban areas reduces continuously and it results in urban flood or stormwater. According to MRLC, up to 40% of land in urban areas or cities is impervious. India has been rapidly urbanizing and in the year of 1950, about 17% population leaves in an urban area but now more than the third part of a total population migrate to urban area or cities in India. In India, many states which are well developed such as Maharashtra, Delhi, Karnataka, Gujarat, Tamil Nadu, Madhya Pradesh suffers from the urban flood from the last few decades. The human factor is the major cause for urban flooding as land use (imperviousness due to urbanization, deforestation, etc), which results in surface runoff in urban areas & sedimentation and the lack of drainage is also cause for urban flooding. The roads, drainage systems get overflow due to heavy rainfall and imperviousness of the area which causes the inconvenience as well as life loss, property loss, many other types of skin diseases, disruption in transportation, electricity transmission, damages of infrastructures, damages to pavements & drainage systems. When the drainage systems have not enough capacity to carry stormwater due to intense rainfall it gets overflow and converted into surface runoff. Recent urban floods include Uttarakhand (2013), Karnataka, Chennai, Assam, Madhya Pradesh, Mumbai, Delhi. Mumbai and Delhi are the cities that are well developed in India and during the rainfall season, the whole era suffers from flooding. Urban flooding is different than rural flooding because of urbanization. Generally, the flooding also depends upon the frequency of rainfall and the volume of runoff on the surface of the area. Due to urban flooding, it has been observed from the last few flood events in the urban area it results in inconvenience to the public to follow their daily routine work. The urban area consists of imperviousness and not equipped with any type of drainage systems and if the permeable pavement constructed directly on the free

drainage sub-surface then storm-water can be directed into the ground (Pratt et al., 1989). Thus the runoff gets overflow on the highways and the drainage systems. This is the major problem in the present study, the pavements are elaborated in such a manner to bear a load of the vehicle as well as to reduce urban runoff. The permeable reservoir pavement constructed at Nottingham, the United Kingdom in 1986 to reduce outflow and improve the water quantity (Pratt et al., 1995). Porous pavements introduced in urban areas to mitigate the urban flow rates and volume results runoff mitigation as an alternative method (Legret et al., 1999). More significantly the impervious area in the urban region as parking lots, driveways and road shoulders, etc. when the traffic is in a higher amount the parking lots used but this occurs often according to the occasions. Thus the parking lots are empty for a long time and rainfall gets spread over the lots can infiltrate if the lots are constructed by permeable material and it reduces the urban flood. Mostly used permeable pavements are the matrix of concrete blocks or plastic web structures with voids filled with sand, permeable soils, and gravel this reduces the impact of runoff caused by development in the urban era (Brattebo et al., 2003). Generally, the impervious surface creates dirt and debris along with runoff over the surface and directed to the water channels. The asphalt repels water to infiltration so by the use of Porous asphalt pavements in different areas as in parking lots, shoulders, footpaths to manage the storm-water (Cahill et al., 2003).

Mostly the urban areas covered by houses, buildings, industries, pavements, compared to trees or forests by which they prevent runoff to infiltrate and mitigates the urban flood. According to which the houses or buildings are connected or to society. Choker course is used for infiltration of runoff and creates temporary storage (McNally et al., 2005; Rogens and Faha, 2007). The pavement constructed over the porous soil then precipitation passes to the soil and effectively reduces the runoff from the pavements area. According to US Environmental protection Agency USEPA, porous pavements can only constructed in the era where the traffic is not so heavy and having slope less than 5% and have deep permeable soil and which also located far away from the water resources which are used for drinking purposes. The comparison is made between the asphalt parking lot and a porous pavement parking lot of grass pavers and the porous lot generated 93% less runoff than the asphalt lot (Dreelin et al., 2006). Development of the permeable pavement as a part of a sustainable drainage system and self-sustainability (Scholz et al., 2007). Permeable interlocking concrete pavement is also a runoff mitigation method from an urban era (Rowe et al., 2008). When the soil below the pavement is not able to infiltrate storm-water sufficiently the under-drain pipes used to mitigate urban flood in permeable pavements (Collins et al., 2008). The base flow enhances partially or fully when runoff infiltrates through the porous media. Permeable pavement is very effective to reduce urban runoff for up to 10 years for 24 hr ARI (Fassman et al., 2010). In Malaysia to reduce surface runoff from the urban region the porous parking lots were constructed (Hamzah et al., 2012). Permeable pavement or porous pavement significantly delays the flood generation from the region and increases significantly the groundwater recharge. Green infrastructure (GI) also helps to mitigate the urban flood effectively. Mostly the areas croplands and forests are covered by lots of buildings, industries, and highways as well in urban development regions which reduce infiltration of precipitation from the soil as well. By the urban flood the parking lots, pavements, sidewalks, footpaths, and drainage systems get chocked, damaged, and destroyed. However, this becomes the loss of human life, properties. Due to the inconvenience of this phenomenon, people suffer a lot of problems regarding transportation, health problem, goods problem, and another type of daily expenses, so it is extremely needed to mitigate urban flood. The green infrastructure (GI) widely used in many cities of the USA, UK, Canada, Germany & New Zealand for a reduction in urban runoff or flooding (Ahiablame et al., 2012). For mitigation of the surface runoff permeable pavement introduced with ground source heat pumps (GSHP), a combination of the renewable energy sources as well (Imran et al., 2013). GI can be used to control the storm-water, maintain it, and restore hydrological and ecological functions (Liu et al., 2014). To mitigate urban flood the LID techniques used but due to lack of adequate modeling tools, it is not suitable for each place for designing and construction purposes (Brunetti et al., 2016). The storm-water can be used for non-potable purposes by using porous asphalt in parking lots located nearly to society. The porous asphalt consists of the high content of voids connected (18-25%) and results to infiltrate the water or store urban storm-water for non-potable purposes as well (Hammes et al., 2018). Permeable interlocking concrete pavement used on parking stalls mitigates the flood peak of about 84%, runoff volume (22%) (Braswell et al., 2018). LID includes permeable pavement and mitigates urban flood. Drainage surface introduced in the driveway, more effectively it reduces surface runoff and

reduction in the surface runoff with an increase in storage thickness (Zhu et al., 2019). Fully permeable pavement, which has all permeable layers is effective to reduce flood from pavements (Saadeh et al., 2019). The full depth permeable pavement (FDPP) used on the top impervious surface of the thin layer to mitigate urban flood and it is effective and cost-efficient according to suitability in highways (Kayhanian et al., 2019). Innovative permeable pavement reduces 90.6 % urban runoff when it is introduced in parking lots with high-density polyethylene liner (Liu et al., 2020).

This study aims to elaborate on the advantages of permeable pavement on impervious surfaces, to mitigate the urban surface runoff which enhances the groundwater recharge. Pavement can be divided into the following parts as roadway, cycle path, sidewalk, etc. The paper also indicates that the use of permeable material in impervious areas for future reference to increase groundwater recharge. The permeable material should be used on the top surface of the drainage system, parking of houses or buildings to mitigate the runoff comes from colonies or societies in the roadway and it prevents the chocking of the drainage system. There are so many experimental works that have been done on permeable pavement or porous pavement in many countries to reduce urban flood at a certain level, which helps to recharge groundwater as well. This improves the techniques to save water from the earth for future reference. In India, this is a common phenomenon, and many states suffering from urban flood and shortage of water supply in the region. Permeable pavers are very useful in cities since porous pavements reduce the effect of urban stormwater and both serve as the best pavement according to BMP's use.

II. RELATED WORKS

Pratt et al. (1989) described the permeable pavement system with four separate sub-base sections to mitigate the urban flood. The study area was taken as Clifton campus of Trent Polytechnic. In the sub-base sections, the four types of stones were used to construct the permeable pavement system. The permeable material used in the sections and it results in flow mitigation from the surface of pavement significantly. From the results, it can be concluded that the peak discharge rate is about 30% of the peak rainfall.

Legret et al. (1999) proposed the pervious asphalt pavement in the catchment of Classerie street The material used for the construction of the structure was geotextile woven, crushed material, porous bituminous-bound, graded aggregates, porous asphalt. In the study, the sidewalks and side parking lots were also constructed as a permeable system. From the study, it is observed that 96% of surface stormwater gets infiltrate immediately and reduces the chances of urban flood significantly.

Collins et al. (2008) developed the four types of permeable pavements and porous asphalt in eastern north California for parking lots. The pervious concrete, two types of permeable interlocking concrete, and concrete grid pavers used as Permeable pavement systems in the study. These four types of permeable pavement systems reduced the stormwater or surface water significantly when compared with asphalt pavement. The surface runoff generation is more in asphalt surface and much lower in the porous concrete surface. And it is observed from the study there are no differences between all permeable pavement systems used in the analysis.

Hamzah et al. (2012) presented the porous parking lots in Malaysia to control stormwater. The material used for construction was granite aggregate for the choker. With the compaction of the soil, the coefficient of permeability decreased. The water flow simulator used in the study and it was able to simulate 1.24-59.89 cm/h rainfall intensity.

Brunetti et al. (2016) defined the low impact development (LID) techniques to mitigate the urban flood flow in Italy. To define the hydraulic characteristics of the permeable pavement the Hydrus-1D model used in the study. The layers of pavement consisted of the base layer and sub-base layer the porous concrete blocks and in bedding layer the ASTM stone gradation. The top layer of the pavement is more efficient to infiltrate the stormwater. The porosity for the base and sub-base course was about 40% and 30%.

Hammes et al. (2018) explored the models constructed as parking lots by porous asphalt to mitigate and store the stormwater in an urban area and to re-use the collected water for non-potable purposes in Brazil. The amount of surface water is filtered and infiltrated through the layers to the storage layer. The runoff water was collected about 80% in parking lots model and about 20 liters of surface runoff for each rainfall event in the study.

Liu et al. (2020) used the innovative permeable pavement (IPP) with high-density polyethylene liner

to reduce the urban flood. Four types of pilot pavements constructed in parking lots of the study area. The impervious concrete pavement, two types of permeable interlocking concrete pavements, and IPP were constructed. The most significant pavement to reduce the urban flood used in the study was IPP and it reduces about 90.6% of surface runoff from the pavement.

III. PERMEABLE PAVEMENT SYSTEMS

With the development of urbanization, it introduces the reduction in infiltration of surface water due to imperviousness, increases surface runoff, and continuously reduces the groundwater recharge so that the introduction of permeable pavement system in the urban areas reduces firstly the urban flood and supports the groundwater recharge. Generally, the urban area consists of imperviousness all around and not properly supported by drainage systems to drain the surface water which converts into the heavy urban flood, which overflows on the roadways and urban drainage systems. Permeable pavement is designed in a way to bear a load of vehicles in all weather. Generally, the permeable pavements consist of porous concrete blocks in the surface course, ASTM stone provided in the base, sub-base, and bedding layers. Permeable pavement will significantly reduce this problem and is the best management practice approach for water resources. Some permeable pavement systems are discussed below:

A. Porous asphalt pavement

The porous asphalt pavement is a kind of polymer-modified asphalt and fibers used in some places. The porous asphalt pavements have more connected voids to infiltrate the surface runoff or stormwater. These pavements are easy to construct and thee work on the pavements is so fast. The cracks and pothole problems do not occur by using this type of pavements in parking lots. The cost of the porous pavement is approximately near the cost of the general asphalt pavement. To store the stormwater the stone recharge bed used in the pavement system. The geotextile fabric used to avoid displacement of the fine material from the sub-grade layer. The sub-grade soil should not be much compacted to encourage the permeability of the soil to infiltrate the water.

B. Pervious concrete pavement

The pervious concrete is the combination of coarse aggregates, cementitious material, admixtures, and few amounts of fines if required. For the pavement design, the flexural strength of the pavement should be good enough. Below the pervious concrete, the open graded sub-base used. And it is designed in a way to provide storage capacity as well. The advantage of constructing the pervious concrete pavement is that it mitigates the heat island effect. It is used in heavy vehicle traffic regions but has some limitations and needed much curing time. This is an effective tool to mitigate the urban flood and can be easily used in urban parking lots, roads inside the colonies, etc.

C. Plastic grid pavers

Plastic grid pavers are also known as grass pavers and gravel pavers. The recycled plastic is used to construct these pavers and is in interlocking blocks or honeycomb shapes. The crushed gravel used in the sub-base layer above the soil sub-grade to infiltrate the stormwater easily. These are so flexible to construct on the uneven surface area. The grass pavers are covered by the grass on the top layer and do not need any type of storage. These pavements are useful in parking lots, residential driveways, sidewalks, fire lanes, etc. The aggregate used in the plastic grid paver needs less maintenance in accordance.

D. Permeable interlocking concrete pavement

These are also called PICP and contains the layer of solid concrete pavers and connected by joints. These joints are filled with small permeable stones. The bedding layer of the pavement is open-graded consists of small-sized aggregates. From sub-graded, the rocks should be removed and filled with open-graded aggregates for permeability. It mitigates the peak discharge from the surfaces and increases the groundwater recharge. The vacuum types of equipment are efficient to clean the surface of pavements. These pavements can be used in driveways, parking lots, walkways, low traffic areas, shoulders of roads.

E. Fully permeable pavement

Fully permeable pavement is those having all layers of the pavement system that should be permeable. It acts as a reservoir to store the stormwater to minimize the runoff. The surface layer can be made of any kind of permeable material like porous asphalt, pervious concrete, etc. the layers below the surface course contain the aggregate with air voids so that the stormwater a store and allow to infiltrate from the layers. To enhance the permeability of the

sub-grade layer it should be less compacted. It can be used in road shoulders, parking lots, streets, highways, and residential driveways, etc. the pavements are very useful and efficient to mitigate the urban flood frequency.

All the permeable pavement systems described above, the construction of the pavement system depends on many factors such as the traffic of the area, characteristics of the soil, climatic conditions and structure of the ground, etc.

IV. FUTURE ENHANCEMENTS

Due to urban flooding, it results in minor to major incidents. So it is essential to mitigate the urban flood as a priority. In India, many states (Maharashtra, Delhi, Karnataka, Gujarat, Tamil Nadu, Madhya Pradesh, etc) are well developed and suffer from urbanization which results in the urban flood and there is the shortage of water supply is also a major issue. The construction of permeable pavements in these states can help to improve the management practices by reduces the flood from pavements and increases the groundwater recharge. Alternatively, the permeable pavement can be provided in parking lots, lawns, roofs, parks, walkways (industries, institutions, hospitals, shopping malls, etc), the footpath of colonies or building area, etc. The surface runoff water can be stored temporarily in pavement systems and further filtered and can be used in non-potable, irrigate the flowers, cleaning of vehicles, etc.

V. CONCLUSIONS

Continuous development in the countries enhances urbanization and it results in urban flood, which is a common disaster and everyone suffers from this in rainy seasons mostly. The roads, drainage systems get overflow due to heavy rainfall and imperviousness of the area which causes the inconvenience as well as life loss, property loss, many other types of skin diseases, disruption in transportation, electricity transmission, damages of infrastructures, damages to pavements & drainage systems. So it is necessary to improve the road constructions to avoid the urban flood. By the use of permeable pavement about 90% of surface runoff can easily infiltrate and results in the reduction of surface overflow and increases the groundwater recharge. Generally, the majority of construction impervious which supports quick runoff generation results in water logging in drainage, submergence of valuable fields. Flood also results from higher precipitation at a place due to cloud bursting. Drainage systems are constructed for discharge but having some limited capacity to carry the flow, they do not serve to reduce the peak flow in urban areas. By this, the permeable pavement provided to mitigate the urban flood by infiltration of runoff from the desired area. It is quite difficult to construct the permeable pavement in heavy traffic roadway, mostly in urban areas. But it can easily introduce the permeable pavement in the sidewalk as well as in cycle path, by which it is easy to mitigate the urban flood from the pavement area. The water can be stored in the temporary storage of permeable pavement systems and convenient to construct and further can be used in non-potable, cleaning of vehicles, irrigation purposes, etc. The construction of the pavement system depends on many factors that should be considered before construction are the traffic of the area, characteristics of the soil, climatic conditions and structure of the ground, etc. The permeable pavement system can easily be constructed in sidewalks, roads inside the colonies, cycle path, shoulders of roads, parking lots, footpaths, etc.

VI. ACKNOWLEDGMENT

The authors would like to acknowledge that the complete review study considered according to the previous research works.

VII. REFERENCES

[1] Ahiablame, L.M., Engel, B.A., Chaubey, I. (2012). Effectiveness of low impact development practices: literature review and suggestions for future research. *Water Air Soil Pollut.*, 223 (7), 4253–4273.
[2] Braswell, A., Winston, R., Hunt, W. (2018). Hydrologic and water quality performance of permeable pavement with internal water storage over a clay soil in Durham, North Carolina. *Journal of Environmental Management*, 224, 277–287.
[3] Brattebo, B., Booth, D. (2003). Long-term stormwater quantity and quality performance of permeable pavement systems. *Water Res.*, 37 (18), 4369–4376.
[4] Brunetti, G., Simunek, J., Piro, P. (2016). A comprehensive numerical analysis of the hydraulic behavior of a permeable pavement. *Journal of Hydrology*, 540, 1146–1161.
[5] Cahill, T., Adams, M., Marm, C. (2003). Porous asphalt, The right choice for porous pavements. Article of Hot Mix Asphalt Technology, September/October (2003) Issue, pp: 26-40.
[6] Collins, K., Hunt, W., Hathaway, J. (2008). Hydrologic comparison of four types of permeable

pavement and standard asphalt in Eastern North Carolina. *J. Hydrol. Eng.*, 13 (12), 1146–1157.
[7] Dreelin, E., Fowler, L., Carroll, C. (2006). A test of porous pavement effectiveness on clay soils during natural storm events. *Water Res.*, 40 (4), 799–805.
[8] Fassman, E., Blackbourn, S. (2010). Urban Runoff Mitigation by a Permeable Pavement System over Impermeable Soils. *J. Hydrol. Eng.*, 15, 475-485.
[9] Hammes, G., Thives, L., Ghisi, E. (2018). Application of stormwater collected from porous asphalt pavements for nonpotable uses in buildings. *Journal of Environmental Management*, 222, 338–347.
[10] Hamzah, M., Jaafar, Z., Ahmad, F. (2011). Laboratory Assessment of water flow simulator for porous parking lots reservoir and soil layers. *J. of Applied Sci.*, 11(20), 3464-3473.
[11] Imran, H.M., Akib, S., Karim, M.R. (2013). Permeable pavement and stormwater management systems: a review. *Environ. Technol.*, 34, 2649–2656.
[12] Kayhanian, M., Li, H., Harvey, J., Liang, X. (2019). Application of permeable pavements in highways for stormwater runoff management and pollution prevention: California research experiences. *International Journal of Transportation Science and Technology*, 8(4), 358-372.
[13] Legret, M., Colandini, V. (1999). Effects of a porous pavement with reservoir structure on runoff water: water quality and the fate of heavy metals. *Water Sci. Technol.*, 39 (2), 111–117.
[14] Liu, W., Chen, W., Peng, C. (2014). Assessing the effectiveness of green infrastructures on urban flooding reduction: A community-scale study. *Ecological Modeling*, 291, 6–14.
[15] Liu, Y., Li, T., Yu, L. (2020). Urban heat island mitigation and hydrology performance of innovative permeable pavement: A pilot-scale study. *Journal of Cleaner Production*, 244, 118938.
[16] Mc Nally, C., Prospo, D., Philo, L., Joubert, L. (2005). The University of Rhode island's permeable pavement materials. Funded by RI HEALTH, Office of Drinking Water, Source water Protection Program.
[17] Pratt C., Mantle J., Schofield P. (1989). Urban stormwater reduction and quality improvement through the use of permeable pavements. *Water Sci. Technol.*, 21(8/9), 769–78.
[18] Pratt, C., Mantle, J., Schofield, P. (1995). UK research into the performance of permeable pavement, reservoir structures in controlling stormwater discharge quantity, and quality. *Water Sci. Technol.*, 32 (1), 63–69.
[19] Rogers, W., Faha, M. (2007). Port of Portland terminal 6 porous pavement project: Sustainable design in a light industrial environment. Article for Land and Water Inc., USA.
[20] Rowe, A., Borst, M., O'Connor, T. (2008). Pervious pavement system Evaluation. Proceeding of the 2008 International Low Impact Development Conference. November 16-19, 2008, Seattle, W. A., pp: 1-8.
[21] Saadeh, S., Ralla, A., Zubi, Y., Wu, R., Harvey, J. (2019). Application of fully permeable pavements as a sustainable approach for mitigation of stormwater runoff. *International Journal of Transportation Science and Technology*, 8(4), 338-350.
[22] Scholz, M., Grabowiecki, P. (2007). Review of permeable pavement systems. *Build. Environ.*, 42 (11), 3830–3836.
[23] Zhu, H., Yu, M., Zhu, J., Lu, H., Cao, R. (2019). Simulation study on the effect of permeable pavement on reducing flood risk of urban runoff. *International Journal of Transportation Science and Technology*, 8(4), 373-382.

IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

ABOUT IJEAST

International Journal of Engineering Applied Science and Technology (IJEAST) is a peer-reviewed, open access journal that publishes high-quality research papers in the field of Engineering, Applied Science and Technology.

IJEAST aims to provide a platform for researchers, academicians, and professionals to share their innovative ideas, research findings, and practical experiences with the global scientific community.

FOCUS AREAS

- Engineering
- Applied Science
- Technology
- Innovation & Development
- Interdisciplinary Studies

PEER REVIEWED
All submissions are rigorously peer reviewed to ensure quality.

OPEN ACCESS
Free and unrestricted access to research for all.

GLOBAL REACH
Connecting researchers and professionals worldwide.

TIMELY PUBLICATION
We ensure a swift and efficient publication process.

For more information, visit our website
www.ijeast.com

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

editor@ijeast.com
www.ijeast.com
India

2455-2143