Prospect of Using Permeable Pavement in Some Regions of Najaf Region

Layth Abdulrasool Mahdi **Hamid Athab Eedan Al-jameel**

Civil Engineering, Faculty of Engineering, University of Kufa, Iraq

Laitha.alasadi@uokufa.edu.iq Hamid.aljameel@uokufa.edu.iq

Submission date:- 11/4/2018	Acceptance date:-27/6/2018	Publication date:-25/9/2018

Abstract

Permeable paving has been vastly utilized as an alternate to traditional impervious hard surfaces, such as street, parking lots, sidewalk and pedestrian areas. This leads to several rain water management and environmental advantage. Therefore, this study has focused on brief the wide-range of permeable pavement systems. These types of permeable pavements have been reviewed in addition to the usefulness of each kind. The results indicated the potential of using such kind in different locations in Iraq is more likely such as Al-Najaf city. Several points of soil investigations have been conducted by previous studies within Al-Najaf city (boundary of Al-Najaf Municipal) prove that Al-Najfa soil is sandy soil. These tested points also demonstrate that the soil characteristics of the city are so suitable for such type of pavement.

Keyword*:* Permeable pavement**,** Pollution**,** Piping systems, Sustainable drainage system**,** Geographical Information Systems

1. Introduction

Most parts of the developed countries depend mainly on piping systems, which were developed over and over in the 19th century. Conventional systems hold the flow of the rain and then divide it to nearby waterways or sewage systems. Some of these systems are incapable and inactive. Moreover, they are usually too expensive [1]. The common standard of permeable pavement systems (PPS) is simply to compile, process and infiltrate any surface runoff to backing recharge of groundwater. Comparing with classic drainage systems, rain water detention and infiltration are able to be maintained at a certain rate or level and cost-effective process, convenient for cities [2]. Furthermore, the PPS has many possibility advantages such as decreasing runoff, sustain groundwater, saving water by recycling and maintain a clean environment [3]. PPS is not only specified as a solution to the sustainable drainage system (SUDS), but as well as a pollutant control technology for runoff from areas utilized as streets or parking spaces where polluted water can seep into the underlying soil. Dangerous pollutants such as hydrocarbons and heavy metals in runoff can compromise soil and groundwater resources when they do not decompose and / or are removed adequately during infiltration [4]. The decreasing in suspended materials, the biochemical requirements for oxygen, the requirements for chemical oxygen and levels of ammonia relative to highways do not presenting the high processing efficiency of PPS, but also there is no requirement for frequent maintenance [3].

In addition, hydrocarbon pollution and the deposition of mineral oil on urban surfaces were the most effectively handle by PPS. Almost all rainwater infiltrated through the PPS, with virtually no runoff. The infiltrating water had significantly decreasing the levels of copper and zinc than the surface runoff of the asphalt area.

2. The Use of the PPS

The PPS is designed to achieve water fineness and magnitude advantage by allowing motion of rain water through the pavement face and into a base/sub base reservoir, the water passes through the pavement materials voids in (or) through the gap between pavers and provides the structural support as traditional pavement. For this reason, permeable pavements can be worked as a standby to traditional road and parking lots. These pavements supply the adequacy to reduce urban runoff and also supply the possibility to alleviate the effects of civilization on receiving water systems by stipulation at source treatment and administration of rain water. The PPS has been shown to enhance the rain water goodness by decreasing the pollutant concentrations, rain water temperature and load of pollutant of suspended solids, heavy metals, polyaromatic hydrocarbons and several nutrients [5].

2.1 PPS

Generally, there are permeable assortment of concrete, asphalt, and interlocking pavers that illustrates depending upon the kind of materials used the PPS are classified into different kind, as indicated in Fig. (1), which are:

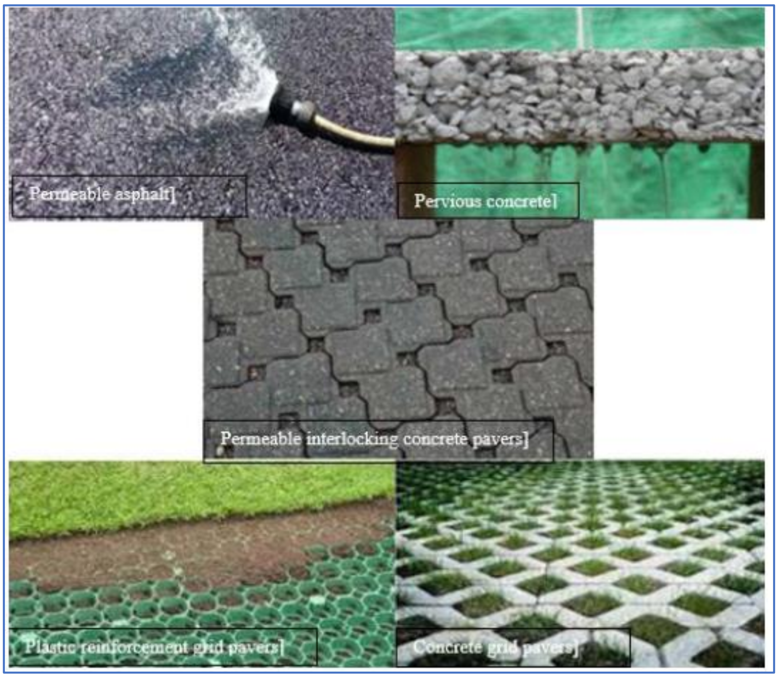

Fig. (1) Different types of permeable pavement systems [5].

2.1.1 Permeable Asphalt

Permeable asphalt, also known as porous, pervious, "popcorn," or open-graded asphalt, is criterion hot-mix asphalt (HMA) with decreasing in fines or sand and permission water to drain through it. It generally consists of coarse and soft aggregate stone restricted by a bituminous-based binder course. Porous asphalt over an aggregate stockpiling bed will minimize rain water runoff rate, volume, and pollutants [5].

2.1.2 Permeable Concrete

Permeable concrete, also recognized as penetrable (or) porous concrete, gap-graded (or) promote porosity concrete is concrete with miniature sand or fines and let water to drain through it. The previous concrete pavement is an effective and unique way to tackle critical environmental problem and assist green and sustainable growth by apprehend rain water and allowing it to infiltrate into the soil. Porous concrete helps recharge groundwater and minimize rain runoff [7].

2.1.3 Permeable Interlocking Concrete Pavement (PICP)

Permeable interlocking Pavement (PICP) consists of producing concrete units that decrease the volume, rate and contamination of rain water runoff. Immobilized modules are designed with little openings between joints. The openings usually consist of 5-15% of the paved flatness area loaded with small and high permeability aggregates. The knuckles allow the rain water to enter the bed layer as a stone break and "open- graded" base i.e., crushed stone layers with no soft or small particles. That backing the pavers whereas providing runoff treatment and storage. The void spaces in the midst of the crushed stones store the water and seep it back in the soil layer. The stones in the joints provide 100% surface permeability, and the essential filters lead to de-watering and reducing contaminants [5].

2.1.4 Concrete Grid Pavers

Concrete grid pavements “green parking lots” offer a cool, green surface as shown in Fig. (1). This could be considered as solution for vehicular access lanes, emergency access areas, and overflow parking areas, and even residential driveways. Grids are confirmed contributors to decrease ambient urban temperatures thereby contributing to decrease heat island in the same time catch some rainfall and runoff [5].

2.1.5 Plastic Reinforcement Grid Pavers

Plastic reinforcement grid pavers also known as geocells which consists of flexible plastic interlocking units that permit for infiltration through large gaps loaded with top soil planted with turf grass or gravel. The sand layer and the basic layer of gravel are often added to raise storage and leakage. Empty networks are usually 90 98 percent of open space, so free space depends on the fill media [8].

3. Previous Studies

The technology has many names: Ground Coupled Heat Pump (GCHP), Ground Source Heat Pump (GSHP), Geo-Exchange (GX), Geo-Thermal Heat Pump (GHP), Earth energy system. Geo exchange systems or Geothermal heat pumps (GHP) are mainly utilized in North America, China, Japan and some European state. Refrigerant are used in GSHP to convey unwanted energy (i.e. Heat) outdoors during summer and into them (if necessary) during the winter [5]. They utilize stable temperatures for surrounding territories, which are less than the similar air temperatures during hot seasons (heat basins) and higher during winter (heat sources). For ground connections, plastic pipes are established inside the soil. Horizontal, vertical, curled or submerged designs applications could be utilized. The main thermal carrier inside the coils is a mixture of water and de-icing factor. The width and length of the rings are determined by the grounding capabilities. The most significant variables are soil type, geology and land area available to these establishments [5].

The environment not only block and minimizes the danger of flooding and pollution of waterways, but also minimizes energy price through the use of green energy (terrestrial energy), which provides several other environmental advantages [9]. Permeable pavement engineering is a functional and easy way to provide structural berths while permitting rainwater to infiltrate so easy out of pavement for a short time storage, rain attenuation, dispersion and reuse. PPS is the suds where water can be treated from urban runoff by sedimentation and filtration for recycling, gathering or reuse. GHPs also pointed out that the source heat pumps are receiving increasing attention on account of their ability to minimize primary energy spending, minimize greenhouse gas emissions and thus decrease the impacts of climate change [10].

The physical reduction of rain water pollutants by permeable pavements with varying designs of geotextile membranes. The research would show reference as to the effects of contaminants existing in urban runoff and the potential of biodegradation by anaerobic operation occurs. One of the guiding basics of SUDS is centered on decrease adverse effects of urban rain water runoff such as increased urban flooding and deteriorating receiving water quality. SUDS such as permeable pavements are commonly perceived as an influential source monitor measure to minimize rain water flows and pollution cargo. However, there have only been little studies aimed specifically at quantifying the impact of utilizing permeable pavements as a source control measure. Using a permeable paving as a storage reservoir, there is considerable potential to reduce the use of primary water for low-grade applications. Water can be stored to wash the toilets, clean the gardens and wash the car in the pavement structure and pump it for reuse [5].

looked at different studies conducted on PPS and their existing usage. Also, examing in brief the detailed design of permeable interlocking concrete pavement. The aspects of maintenance and water quality related to the practitioner were described in the porous paving systems. The water quality concepts are focused on it. Recent innovations were highlighted and explained, and their potential for further research work was outlined. The neoteric innovations like evolution of a combined geothermal heating and cooling, treatment of water and recycling pavement method is promising, and it is in detail in abbreviate, future research works are outlined in summarized. These PPS are changing the way we development respond with the natural ambience. Its usage towards parking lots, highways and even airport runways are all refinement in terms of water quantity, quality and safety [5].

The decreasing of pavement crosses grades of main urban streets and city arterials with detach carriage ways can be done as show in Fig. (2) in two ways: by rotating a traveled way about the outside lateral edges of pavement face or about middle edges. In the first situation elevation levels of the extreme curb elements beside the ends of the traveled path stayed with no change in it, while the elevation heights of the curbs along the intermediate edges reduced. The benefit of this process of the traveled way super elevation is that the height of the elevation along outside edges of pavement stay the same, beside elevations of existing rain water inlets. However, in order to build a stable and flat base course for the new layers of porous asphalt a large part of the layers of current pavement structure, thorough a wearing course, have to be taken away. In the second situation, by rotating a traveled way about intermediate edges, all structures which were constructed next to the pavement edges are reduce it work ability very much due to the lifting of elevations of side curbs along the outside edges of travelled path. For primarily ranked urban paths whose edges are not exceed with buildings and houses, this super elevation process for lessening pavement cross grades is a best solution liken to the super elevation manner applied in the first case. Porous asphalts are applied all over the world to decrease the impact of noise caused by daily traffic. In additional to the effect of noise lowering, due to their exposed texture and drainage characteristics are improved, porous asphalts reduce the influence of spraying water backwards of a moving car. Since drainage ability of porous asphalt as a surface permeable layer is a lot higher matched to a conventional dense-graded asphalt surface course, the amount of cross grades of pavement wearing course on the street sections with porous asphalts should be considered additionally as show in Fig. (3) [11].

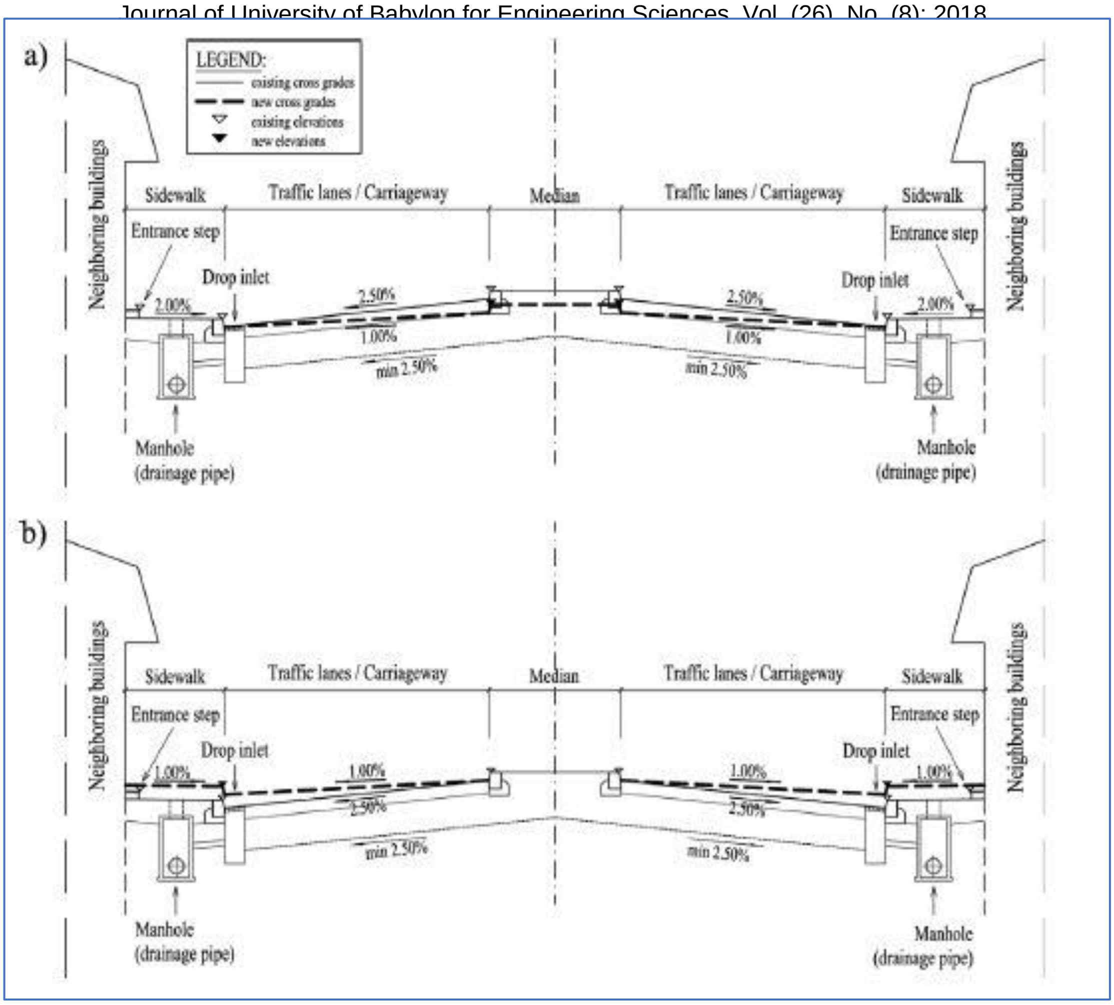

Fig. (2) Simplified cross sections of urban road, which illustrate the effects of, cross grade reduction by revolving a traveled way: a) about the outside lateral edges of pavement surface; b) about median edges [11].

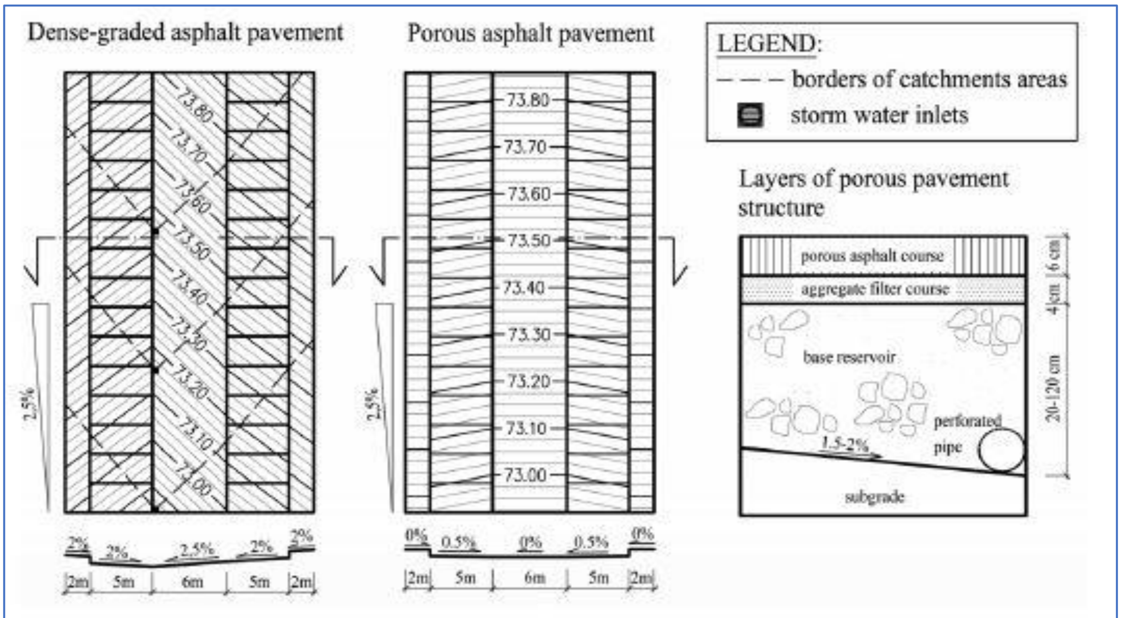

Fig. (3). Changing of pavement cross grades at parking lot after the construction of wearing course of porous asphalt over water permeable base with reservoir [11].

Urban ecosystems usually threaten by Water runoff from exposed surfaces, people health values and property. classical rain water arrangement systems are often overwhelmed by massive rains, leading to the assessment of substitutional green infrastructure (GI) strategies to make rainwater management more efficient. Here, we offer a synthesis to locate the effectiveness of GI reservoirs, filtration equipment, biological infiltration, construct wetlands, green roofs and accessible stands - minimize runoff and peak flow levels and decrease the load of water pollutants by experimenting and using agents such as total suspended solids (TSS) and total nitrogen (TN) from rain flow. Overall, all infrastructure lowers the amount of rainwater and / or develop the quality of runoff water on a local scale, and its performance was similar to the traditional rainwater administration approach (i.e., the catchment basins). There was common harmony between the data reviewed by colleagues and the best management practice database (BMP) for maximum GI efficiency, especially with regard to water goodness [11].

Hein [12] working and maintenance direction is providing to guarantee that permeable pavements job properly by supplying rain water infiltration and structural support for the expected traffic volume. Protective servicing treatments decrease the danger of premature deterioration, reduce the rate of the progression of defects, and the relationship between the cost and the effectively expands the life of the pavement. The key for cost-effective protective servicing is applying the suitable treatment at the suitable time. The purpose of a preventative maintenance plan is to recognize those sections that would capitalize most from protective servicing, make the identification in a timely manner and choose and apply the most profitable treating. Examples of clogging are illustrated in Fig. (4a, 4b, and 4c):

(a) Low severity clogging **b) Medium severity clogging** **(c) High severity clogging**

Fig. (4) Examples of clogging [12].

Very little facts have been made obtainable on the possible risks to humans from the microbiological pollution of this water, partly because of the understanding low risk from this kind of reservoir. Escherichia coli strain B was appended at a concentration of 2.0x109/m2 to permeable pavement models and washed through with a high intensity rainfall, Removal performance of the bacterium was with a range of 50 % after the initial rainfall phenomenon but the cell density of E. coli in pavement effluent reduce rapidly in the first three weeks. The reuse and recycling of storm water, using paving as a storehouse for storage, display large possibility for decreasing the use of main water for low-grade uses. Water can be stored to wash the toilets, clean the gardens and wash the car in the pavement structure and pump it for reuse [13].

The percentage of state-equivalent herbs is used to measure the number of porous pavement as if it was 40% non-permeable surfaces and 60% permeable surfaces. The "60% balance" permit developers to consider just 40% of the separate pavement as a built-up region. As a result of this credit, developers are at present able to evade installing other, more expensive, rain water practices, like wet basins. Studies have also present that for optimal hydrological performance, porous piers must be identified away from sites prone to sediment piling up, built with a washed stone storage basin and preserved by a vacuum cleaner on a frequent basis. Since sites with padded storage tanks do not efficiently rise soil leakage, credit has been proposed only for separate paving sites in sandy soil environments. Figs 5a, 5b and 5c show three of the most popular sidewalks: discrete concrete floors (PICP), concrete grid floors (CGP), and separate concrete (PC). CGP contains both internal spaces and distance between individual paving. PICP are concrete paving floors when installing spaces in corners and midpoints of paving. The PC differs from standard concrete in taking out fine aggregates from the mix, permitting the formation of vacuum spaces connected during processing. The runways permit drainage through the existence or formation of these spaces [6].

Kevern [14] presents a unique range of permeability, leakage, and clogged test results to prepare basic information for the design and requirements of soluble concrete-resistant concrete pavements. Advance cylindrical samples of different sizes and porosity were examined using the head readiness scale in the laboratory. The effect of the cylindrical wall on porosity and permeability was calculated using image analysis in the same time with test changes. The infiltration was tested on a series of constant plate samples that were then clogged by manure, soil, compost of soil and mixture. The efficiency of cleaning was calculated and linked to the characteristics of the sample. The results presented that the permeability of the cylinder was very variable, with 100 mm samples producing the least fluctuation of the tested volumes (75 mm and 100 mm). The samples of the tile with fixed transverse filtration were the most resistant to coagulation and had the better filtering after cleaning. Samples with a primary capacity of 750 cm / hr or more were the most resistant to coagulation. The top pavement performance due to the distribution of a single vertical permeability and high primary infiltration ability.

PICP **(b) CGP** **(c) PC**

Fig. (5) Three of the most common permeable pavements [6].

Concentrate on the impact of rainfall concentration and its interval, in addition to the slope of the pavement, on blockage and blockage operations. Rainfall simulation was applied to experience porous asphalt and previous concrete specimen with void ratio of 15, 20 and 25%. To simulate the reduction of permeability in separate docks during their service period, the test samples were filled using 3 various sediment concentrations: 0.5, 1.0 and 2.0 kg / m 2. The 3-various rainfall concentrations are (50, 100 and 150 mm/h) with duration of two types (15 and 30 minutes) on the test samples. The ability to infiltrate test samples was assessed in newly constructed conditions and for each clogging scenario before and after precipitation simulations. The results showed that precipitation manner in additional to the slope of the pavement influenced significantly on the infiltration ability of the clogged substances, which are higher after longer periods of heavy rainfall and minimize pavement slopes. In general, the PC mixes present better execution in terms of intrusion ability and self-cleaning efficiency. This paper offers a unique combination of permeability, leakage, and clogged test results to supply basic information for the specifications and design of soluble concrete-resistant concrete pavements [15].

Scholz and Grabowiecki [9] reported that hydrocarbon contamination and deposition of mineral oil on urban surfaces were the most common problems for PPS systems. Research has also present that the same structure can be used as an efficient bioreactor at site, porous asphalt or pavement of the equivalent of conventional asphalt, except it relatively porous. It contains of asphalt and open concrete grades on an open, graduated aggregate base over good drying soil. Porous concrete pavement consists of aggregates and cans of Portland cement. Porosity is supply by the omission of soft aggregates. The standard interlocking concrete units for the type of internal discharge chamber are either cast or cast in place or from concrete or plastic concrete, which contains open cells.

Using the secondary data collection approach is to achieve knowledge gaps surrounding permeable pavements. The major findings are the impact of pressure using monitoring tests and the infiltrometer to convey what the compact effect has on the various sidewalks. It was used to delay drainage holes to allow sediment to pass through paving, creating additional permeable areas to increase drainage rates and pavement age. Various maintenance techniques were tested and tested for the most effective technical methods. The pressure-wash test, truck unloading, milling, and air freshener proved to be effective maintenance methods by rising pavement leakage rates to full potential.

Wallace [16] conducted the research to improve the hydrological performance of the accessible berths. (PICP) proved to be highly vulnerable to vehicle loading operations and had very low leakage rates compared to concrete Grass pavements (CGP). The oversight of PICP, permeable asphalt (PA) and permeable concrete (PC) pavement notes proved that the PC is the most durable. The top layers of pavements appear to be the most vulnerable to the occlusion. Fig. (6) indicates a construction of an accessible pier. (Layer 1) PICP (not yet built) The bedding layer (pebbles) appears on top of the first ground camouflage. Under the black geotextile was the subgrade and the white bottom geotextile.

Fig. (6) Construction of permeable pavement [16].

Brattebo and Booth [4] evaluated the long-term efficiency of pavement permeability as a substitution to classical asphalt pavement impervious to the parking area. Four types of commercially available paving systems were put under evaluation after 6 years of daily parking use for structural durability, infiltration capacity and impact on infiltrated water goodness. All four separated pavement systems did not show any signs of corrosion. Almost all the rainwater leads through the runways, with nearly no runoff. The infiltrating water had significantly lower levels of copper and zinc than the surface runoff of the asphalt area. The oil from car motor was reveal in 89% of samples of runoff from asphalt but not in any sample of water penetrate through the jetty. Lead or diesel fuel is not detected in any sample. The infiltration width measured five years earlier had significantly higher concentrations of zinc and significantly lower concentrations of copper and lead. Every permeable pavement kind had two parking stalls twin into one instrument station.

3. Summary of some of the previous works

Table 1 summaries the most studies about permeable pavements.

Table 1 Previous studies relating to permeable pavements.

No.	The Authors	Their work	Their conclusions
1	Schluter and Jefferies [1]	Modeling the outflow from a Porous Pavement.	The modelling outcome have shown a perfect prediction of the outflow attitude of the site investigated.
2	Brattebo and Booth, [4]	Discussing the long-term efficiency of PPS.	Using PPS lowering the levels of copper and zinc.
3	Hunt and Bean [6]	Impact of grass percentages on PPS.	Permeable pavements have been sited away from locations prone to sediment accumulation
4	Scholz and Grabowiecki [9]	Influencing of PPS on mineral oil deposition and hydrocarbon pollution onto urban surfaces.	The structure itself can be used as an effective in-situ aerobic bioreactor.
5	Nnadi et al. [13]	Studying the impact of PPS on the potential risks to humans.	The use of permeable paving for storage as a reservoir, show great possibility in the lowering of mains water use for low grade uses.
6	Kevern [14]	Permeability was specified by using image analysis in the same time with testing variability.	The best pavement execution resulted from regular vertical permeability distribution with high initial infiltration capacity.
7	Wallace [16]	Optimizing the hydrological performance of PPS.	The testing had all confirmed to be successful maintenance ways by increasing infiltration rates of pavement to entire capacities.
8	Booth and Leavitt [17]	The impervious surface contribution to the disrupted runoff processes in an urban watershed is massive.	PPS is promising substitutional approach to decrease the downstream consequences of urban development.
9	Asaeda and VU [18]	Discuss heating effects of the PPS.	Using PPS decrease the atmospheric heating rate.
10	Krishnan [19]	Studied the impact of air motion in voids of PPS.	Tribulation due to water produce damage and bleeding accelerates the deficiency of an asphalt concrete pavement
11	Lucke and Beecham [20]	Mentioning the influence of PPS on clog quickly, high servicing, and replacement costs.	The study clearly demonstrated that the infiltration rate of permeable pavements minimizes over time.
12	Drake et all [21]	Discussing the PPS to mitigate the impacts of urbanization on receiving water systems.	The PPS can be used to minimize pollutant concentrations.
13	M M YU et al. [22]	This paper set the design system of city street flooding from the macro, medium and micro level.	The researcher set an urban pavement sponge system under the territorial ecological pattern.
14	Yuan et al. [23]	Analyzing using the life cycle assessment approach.	By difference, cement and crushed gravel are the key materials for permeable brick that the reason for the most environmental impacts.

4. Chemical and Physical properties of Najaf subgrade soil

In order to understanding the physical and chemical properties of Najaf subgrade soil, Mauff [24] make an investigation for this purpose, in addition to check the underground water location, a laboratory work is made to the soil sample to recognize these properties which include physical and chemical properties.

The investigation show that the water table locate at the same elevation of the river water and the permeability coefficient is ranges (7x10-3 – 3.92x10-6) due to disparity increase of percentages in the sub-layer soil, the plastic index and liquid index of the soil. In addition, the study shows that the water table at (1.0-1.5) m from the natural ground surface and the soil is silty sandy.

Another study is made for the sub-soil of Najaf by Al-Mamoori [25], the object of this study is to make database for the gypsum content by making geotechnical maps to assist the display the vertical & horizontal gypsum content. To do that, 464 boreholes selected and analysis by using Geographic Information System (GIS).

The information that managed in this study were pick from the National Center for Construction Laboratories and Researches (NCCLR)/Babylon laboratory reports, the results present that the large percent of study region for the depth 0-4m had gypsum content between 10-25% (moderately gypsiferous), on the other hand, for depth 4-8m had gypsum content 3-10% (slightly gypsiferous).

The British Standards [26] indicate that the gypsum percent in the soil must not more than 20.5% and for road not more than 10.75%, the Iraqi Standards for Road and Bridges 1983 indicate that gypsum percent must be not more than 10%. The properties that covered by Al-Mamoori [25] are: Chlorides, Sulphate, Gypsum, Calcium.

5. Applicability of using permeable pavement in Al-Najaf city

Referring to the above permeable pavement technique mention before, it was obvious this type of pavement is more suitable for sand soil. According to visual survey, it was clearly that All-Najaf city is not clay; it is mostly sand soil. Whereas, the soil of Al-Kufa city is mostly a clay soil. This is due to closeness from Euphrates River. Khadim and Al-Baaj [27] used Geographical Information Systems (GIS) to produce a geotechnical map for gypsum for soil of AL-Najaf Governorate- Iraq as shown in Fig. (7). Geotechnical maps give a powerful database and strong visual presentation of geotechnical data. Its geographical area extends between longitudes (42º–44º45’) Eastwards and (29º50’–32º21’) latitudes Northwards by degrees system.

This study shows an important point, which is that, a soil of Al-Najaf city is a layered soil, these layers are: clayey sand, silty sand, gypsum and sand distributed randomly on the depths and it is very suitable for use permeable pavement with it.

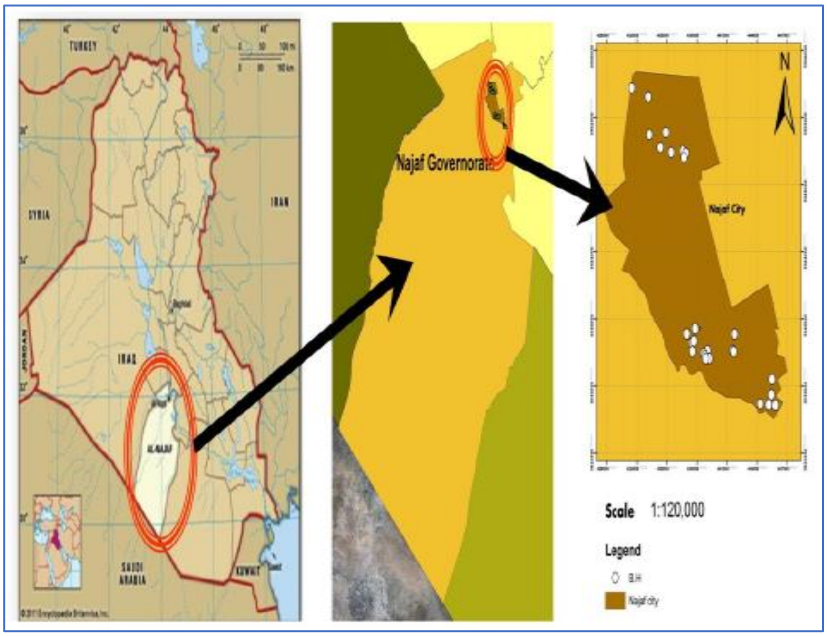

Fig. (7) Geotechnical map for gypsum for soil of AL-Najaf Governorate- Iraq [27].

Through other studies such as Al-Maliki [28], which study the bearing capacity of AL-Najaf city, it was found that most Al-Najaf city soil is sandy soil as shown in Fig. (8) Which represents the base layer for all pavements there.

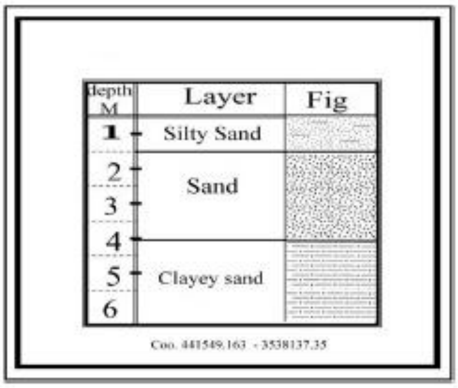

Fig. (8) Samples of boreholes in Najaf City [27].

6. Conclusions and Recommendations

The main conclusions come up with this study could be summarized as following:

1. This type of pavement is more suitable to Iraq environment especially in Al-Najaf City due to high temperature and drainage problem in pavements and poor maintains.
2. Through other studies, it was found that most Al-Najaf city soil is sandy soil which represents the base layer for all pavements there.
3. This study recommends using GIS in determining the suitable type of soil which fits the use of permeable pavement.

CONFLICT OF INTERESTS.

There are no conflicts of interest.

References

[1].Schluter W, Jefferies C. "Modeling the Outflow from Porous Pavement", *Journal of Urban Water*, Vol. 4(3), pp. 245-253, 2002.

[2].Dierkes C, Go¨ bel P, BenzeW, Wells J**,** "Next generation water sensitive rain water management techniques" In: Melbourne Water, editor. Proceedings of the *second national conference on water sensitive urban design*, Brisbane, Australia, 2–4 September 2000**.**

[3].Pratt, C., Newman, A., and Bond, P., "Mineral oil biodegradation within a permeable pavement: long-term observations", *Journal of Water Science and Technology*, Vol.39(2), pp.103–109,1999

[4].Brattebo, B., and Booth, D., "Long-term rain water quantity and quality performance of permeable pavement systems", *Journal of Water Research*, Vol.37 (18), pp.4369-4376, 2003.

[5].Kumar, K., "Review on permeable pavement systems", in *Transportation planning and methodologies Conference for developing countries (TPMDC-2014)*, Vol.11**,** BOMBAY, 2014.

[6].Hunt, W.F., and Bean, E.Z., "NC state university permeable pavement research and changes to the state of NC runoff credit system", *8th International Conference on Concrete Block Paving, November 6-8, 2006 San Francisco, California USA*.

[7].Gajda, J., and Van Geem, M.,*"A Comparison of Six Environmental Impacts of Portland Cement Concrete and Asphalt Cement Concrete Pavement*", PCA R&D Serial No. 2068, Portland Cement Association, 1997

[8].Ferguson, B. K. *Porous Pavements*, Boca Raton, Fla.; London: CRC, 2005.

[9].Scholz, M. and Grabowiecki, P., "Review of permeable pavement systems", *Journal of Building and Environment*, Vol.42 (11), pp. 3830–3836, 2007.

[10]. Tota-Maharaj, K., and Scholz, M., "Permeable (pervious) pavements and geothermal heat pumps: addressing sustainable urban rain water management and renewable energy", *International Journal of Green Economics*, Vol. 3(3), pp.447-461, 2009.

[11]. Ilic, V., Orešković, M., and Gavran, D., " The use of porous asphalt for the improvement of the grading plan geometry and drainage of pavement surfaces on urban roads", *International Congress on Transport Infrastructure and Systems,* TIS Roma 2017, Rome, Italy

[12]. Hein, D.K., "Maintenance Guidelines for Permeable Interlocking Concrete Pavement Systems", in *International Conference on Concrete Block Pavements*, Dresden, Germany, 2015.

[13]. Coupe S., Nnadi, E., and Oyelola, O., " Water recycling using permeable paving as the source: Biological water safety and the fate of introduced contaminants', *11th International Conference on Urban Drainage*, Edinburgh, Scotland, UK, 2008.

[14]. Kevern, J., "Evaluation Permeability and Infiltration Requirement for Pervious Concrete", *Journal of Testing and Evaluation*, Vol. 43(5), pp. 544-553, 2015.

[15]. Brugin B., Marchion M., Becciu G., Giustozzi F., Toraldo E., Andres-Valeri V., "Clogging potential evaluation of porous mixture surface used in permeable pavement systems", *European Journal of Environmental and Civil Engineering, 2017.*

[16]. Wallace, D., "Optimizing the Hydrological Performance within Permeable Pavements", BEng Thesis, Civil and Transportation Engineering, Edinburgh Napier University, Edinburgh, Scotland, 2017.

[17]. Booth, D., and Leavitt J., "Field evaluation of permeable pavement systems for improved rain water management", *Journal of American Planning Association*, Vol.65 (3), pp.314–325, 1999.

[18]. Asaeda, T., VU, C., "Characteristics of porous pavement during hot summer weather and impaction the thermal environment", Journal of Building and Environment, Vol.35 (4), pp. 363-375, 2000.

[19]. Krishnan, J., and Rao, C., "Permeability and Bleeding of Asphalt Concrete Using Mixture Theory", in *International Journal of Engineering Science*, Vol.39 (6), pp.611-627.April 2001. 611-627.

[20]. Lucke, T., and Beecham S. "Field Investigation of Reduction in Infiltration Capacity in a Permeable Pavement System Due to Clogging", *Journal of Building Research & Information*, Vol. 39(6), 2012.

[21]. Drake, J., Bradfrd. A. and Seters T.V., "winter effluent quality from partial-infiltration permeable pavement systems", *Journal of Environmental Engineering*, Vol. 140(11), 2014.

[22]. Yu, M., Zhu, J., and GAO, W. "Urban permeable pavement system design based on sponge city concept", *3rd International Conference on Water Resource and Environment*, Vol.82, 2017.

[23]. Yuan X., Tang Y., Li Y., Wang Q., Zuo J., "Environmental and economic impacts assessment of concrete pavement brick and permeable brick production process -A case study in China", *Journal of Cleaner Production,* Vol.171(10), pp.198-208, 2018.

[24]. Mauff, K.R., "Geotechnical evaluation of some properties of the physical and chemical soil selected sites in NAJAF-Iraq", *Journal of Babylon University/Engineering sciences*, Vol. 25(2), 2017.

[25]. Al-Mamoori, S.K., "Gypsum Content Horizontal and Vertical Disribution of An-Najaf and Al-Kufa Cites' soil by Using GIS", *Basra Journal of Engineering Sciences*, Vol. 17(1), 2017.

[26]. BS 1377-3:1990. "Methods of Test for Soils for Civil Engineering Purpose", Part 3: Chemical l& Electrochemical Tests.

[27]. Khadim, A., Al-Baaj, A.J., " The geotechnical maps for gypsum by using GIS for Najaf city", *International Journal of Civil Engineering and Technology*, Vol.7 (4), pp.329-338, 2016.

[28]. Al-Maliki, L.A.J, Al-Mamoori, S.K., El-Tawel, K., Hussain, H.M., Al-Ansari, N., and Al Ali, M.J., " The geotechnical maps for gypsum by using GIS for Najaf city", *Journal of Scientific* Research, Vol. 10, pp (262-269), 2018.

افق استخدام التبليط النفاذ في بعض مناطق مدينة النجف الاشرف

ليث عبد الرسول مهدي   حامد عذاب عيدان ال جميل

القسم المدني، كلية الهندسة، جامعة الكوفة

Laitha.alasadi@uokufa.edu.iq   Hamid.aljameel@uokufa.edu.iq

الخلاصة

التبليط النفاذ له استخدامات واسعة كبديل عن التبليط الصلب غير النفاذ كما في الشوارع والساحات والارصفة ومناطق المخصصة للمشاة. هذا التبليط يقود الى فوائد ادارة مياه الامطار وفوائد بيئية. لذلك هذه الدراسة ركزت على تقديم مختصر عن انظمة التلبيط النفاذ. هذه الانواع من التبليط النفاذ قد تم استعراضها بالإضافة الى فائدة كل نوع. النتائج بينت امكانية استخدام هكذا نوع في مواقع مختلفة من العراق كمدينة النجف الاشرف. نقاط عديدة من تحريات التربة والتي اجريت بدراسة سابقة في حدود بلدية النجف بينت بان طبيعة تربتها هي تربة رملية وان مستوى المياه الجوفية منخفضة جدا. لذلك فان هذه النقاط اثبتت ان خصائص التربة هي جدا مناسبة لهذا نوع من التبليط.

الكلمات الدالة: التبليط النفاذ، التلوث، نظام الانابيب، نظام المجاري المستدامة، نظام المعلومات الجغرافيه**.**