POROUS ASPHALT PAVEMENT

SWETTI JHA, assistant professor, New horizon college of Engineering, Bangalore India,

swettijha@gmail.com

Abstract: - Present study is carried on making progress towards best possible way to develop urban areas by improving transportation along with systematic runoff and ground water recharge .Now a day's many cities facing problems in draining of storm water & scarcity for water. Every year we receive large amount of rainwater which is not collected or drained it will damage the road as well increase rick of accidents .this can be eliminated collecting rain water on porous pavement surface .By using different sizes of mineral admixtures with its gradation increasing voids content and introducing Demolished Waste as replacement of aggregates of different proportion ,by analysing & testing to know best proportion of mix with optimum bitumen content ,marshal stability mix design , comparison study between Indian standard mix pavement , economical , durable green asphalt, maximise utilization application of pavements in different zones

The porous asphalt pavement which can be used for parking lot or low-trafficked roads/streets works like this. The top 75 mm asphalt layer is specially designed to make it porous. Rainwater goes through it rapidly without any ponding. The water is then stored in an underlying open-graded stone bed, which is about 225 mm thick. From there, water percolates slowly into the underlying soil. The porous parking lot or street can be integrated with a roof rainwater harvesting system in the buildings adjacent to it by diverting the roof water to the stone bed. Recently, the Jaipur Development Authority has constructed the first ever porous asphalt parking lot in India. This paper gives the details of its design, construction, and performance.

Keyword: porous asphalt pavement

I. INTRODUCTION

One of the techniques to improve storm water management is porous pavement, which can be used on parking lots, the surface courses of highways, and light-traffic roads or streets. Traditionally, the surfaces of these facilities are built with impervious materials, which often replace the original vegetation that effectively reduces peak runoff volume and even absorbs some pollutants. In an event of rainfall, the motor oil, grease, paints, and rubbers on the impervious pavement surface are quickly picked up by the runoff, flow through the drainage systems, and end up in water bodies. Porous pavement can facilitate infiltration of the runoff into the ground and cuts the peak volumes. This provides advantages of ―reducing downstream flooding, limiting surface water pollution, recharging aquifers, and—in certain urban areas—reducing the frequency of combined sewage overflow problems [8].‖ The porous pavements on highways, often termed as open-graded friction course (OGFC), are built for other purposes, primarily to reduce the safety hazards related to hydroplaning, splashing .The purpose of this research is to study the durability, maintenance requirements, hydrologic benefits, and environmental considerations of a full-depth porous asphalt (PA) pavement, installed on a low-volume roadway…..Among all the transportation systems road ways is most commonly used transportation system. But in present scenario roads face a lot of problems like potholes, cracks and many other distresses. Not even these but water is also the main enemy to the pavement which causes deformations and changes the texture of sub grade soil resulting a large variation. These are caused because of the irregular formwork of drainage to drain out rain

Water; as result water gets stagnated on the road. After a long period of time these waters gets percolated into the pavements through cracks on the road, causing many distresses which are mentioned above. But these waters can be used if they are collected properly. Saving of rain water is a major issue in cities when they are getting urbanized. Rain water form many places like domestic, commercial are getting wasted by accumulating on the roads (as they are rigid and impervious layer) which will cause many distresses and problems (loss of visibility of road and loss of lives of humans), due to this impervious layer maximum amount of rain water is going in vain (drainage). So to eradicate these problems and save the rain water, roads must be designed in such a way that the water which is accumulated over the surface of it should be collected and

 DOI : 10.18231/2454-9150.2019.0308

can be used for various and basic needs. Hence introduction of POROUS ASPHALT PAVEMENTS in the place of normal pavements should come into existence to collect the rain water from the surface only. The Main objective is to collect the storm water and use them again, Decrease soil Erosion at shoulders as water will not flow at the shoulders and finally increase the ground water recharge. We can also increase the ground water table recharge level by keeping the recharge beds of thickness not higher than 6-8 ft. at the bottom of pavement which will directly percolate the collected rain water into the underground layers and hence we can increase the ground water table recharge also. An appropriate design has been done on the section (layers of pavement as per the CBR obtained in the field) of the pavement using IRC Method, introducing geo-cells and geo tubes to give additional support strength to the pavements. As a result Porous Asphalt Pavements can also be recommended to implement in India. Then after a comparison had been done with a nominal mix which is prepared according to the Standards. These sorts of asphalts have a big number of merits than demerits as the principle issue in the nation is draining the tempest water and utilizing.

The evolution of road industry and the tremendous surge in number of vehicles on roads has been a rationale that has promoted exploiting all viable available resources to build better roads of prolonged service life. Incorporating unconventional construction material in the road construction commenced in the 80's where conventional raw materials such as bitumen, crushed aggregates, and unbound aggregates mixtures began to scarce. The process of producing aggregates materials has been causing extreme disruption to the environment and to the economic owing to the severely depletion the natural resources. Furthermore, the alarming rate of increased waste production is what underpins the efforts to investigate the potential incorporation of various by-products in road construction.

The processing cost, the engineering properties, the evidence that demonstrate the viability of the material and its positive impact on the long-term performance of the road construction works are what characterizes and favors the use of that specific material. Agencies investigated several green materials technologies that reduce environmental effects and use recycled materials in infrastructures applications. The researchers developed several green material technology programs, which maintain or improve current practices in construction engineering and ensures green products or methods arising from these programs would be cost effective and would confer benefits on society, the economy and the environment.

Porous asphalt which integrates ecological and environmental goals for a site with land development goals, reducing the net environmental impact for a project. Not only do they provide a strong pavement surface for parking, walkways, trails, and roads; they are designed to manage and treat storm water runoff. With proper design and installation, porous asphalt pavements can provide a cost-effective solution for storm water management in an environmentally friendly way. As a result, they are recognized as a best practice by the U.S. Environmental Protection Agency (EPA) and many state agencies

Due to current requirements for management of storm water runoff, a number of new technologies have emerged in recent years to manage both the quality and quantity of storm water runoff associated with urban development. One technology that has received increased attention is porous pavement. Porous pavement allows disposal of runoff via direct infiltration from the developed surface. This ability to use paved surfaces to dispose of storm water offers a number of benefits including; efficient use of developable land by utilizing the paved footprint on a site for storm water management

PA is used worldwide for its favorable splash and spray properties and its reduction of aquaplaning under rainy conditions as well as its noise reduction properties porous asphalt acts as a drainage layer, enabling rainwater to percolate through the mix, thus light reflection and headlight glare, some of the dangerous factors for drivers especially in night time, decrease dramatically and lane markings are enhanced clearly on wet surfaces. Road surfaces are laid with coarse macro-texture, which are in contact with the tire tread. This texture is known to contribute to the noise absorption between the surface and the tire.

Increasing skid resistance under wet conditions is one of the main reasons for using porous asphalt. Assuming that a rougher wearing course would increase frictional properties. In Oregon friction properties of porous asphalt were compared with dense graded asphalt. The data accumulated indicated that porous asphalt mixes had slightly improved friction properties in dry conditions and a much improved friction properties during rainy conditions when free water was present on the pavement

Porous asphalt consists of standard bituminous asphalt in which the fines have been screened and reduced, creating void space to make it highly permeable to water.

Porous asphalt has the positive characteristics of an ability to blend into the normal urban landscape relatively unnoticed. It will typically allow a reduction in the cost of other

Storm water detention infrastructure by increasing the time of concentration and reducing the peak discharge rates for the larger storms. This can offset the somewhat greater placement cost over traditional impervious pavements. A drawback is the cost and complexity of porous asphalt

 DOI : 10.18231/2454-9150.2019.0308

systems compared to conventional pavements. Porous asphalt systems require a modified construction protocol for equipment and placement than is typical for regular asphalt pavements. The level of construction workmanship is not necessarily more difficult, just different As with other pavement systems.

Therefore, this unique structure is expected to be introduced in their urban areas on a regular basis to meet the high environmental demand.

The purpose of this study is to investigate the use of alternative porous pavement materials as well as to refine porous pavement design process. It is expected that the study will advance knowledge on porous pavement and make them more durable, economical, and environmentally friendly

II. METHODOLOGY

The porous asphalt itself are located the porous media infiltration beds (Figure), from top to bottom: a 4" – 8 "(10 - 20 cm) (minimum) thick layer of choker course of crushed stone is preferable to alleviate compaction issues with the porous asphalt) an 8" to 12" (20 cm to 30 cm)minimum thickness layer of filter course of poorly graded sand (a.k.a. bank run gravel or modified 3" (8 cm) minimum thickness filter blanket that is an intermediate setting bed (pea gravel) and a reservoir course of crushed stone, thickness dependant on required storage and underlying native materials. Alternatively, the pea gravel layer could be thickened and used as the reservoir course depending upon subsoil suitability. This alternative simplifies subbase construction. For lower permeability native soils, perforated or slotted drain pipe is located in the stone reservoir course for drainage. This drain pipe can be day lighted to receiving waters or connected into other storm water management infrastructure (wetland, storm sewer, etc.). The fine gradation of the filter course is for enhanced filtration and delayed infiltration. The high air void content of the uniformly graded crushed stone reservoir course: maximizes storage of infiltrated water thereby allowing more time for water to infiltrate between storms; and creates a capillary barrier that arrests vertical water movement and in doing so prevents winter freeze-thaw and heaving. The filter blanket is placed to prevent downward migration of filter course material into the reservoir course. The optional under rain in the reservoir course is for hydraulic relief (typically raised off of the bottom of the reservoir stone layer for enhanced groundwater recharge).

III. MATERIALS

1.3.1 Bitumen

Bitumen is, basically, a form of petroleum. It is sticky, black and highly viscous and comes in liquid or semi-solid form It is also commonly used to make bituminous waterproofing products, including roofing the use of bitumen in a high range of applications Bitumen has been use for various purposes including road making, Now, the main use of bitumen is in the road making industry for construction and maintenance. In road making, bitumen products are typically applied here, it is used as a glue or binder and mixed with aggregate particles to form asphalt concrete. The strong adhesion that occurs between the bitumen and mineral aggregate enables the bitumen to provide mechanical strength for the road. Bitumen is difficult to work with an ambient temperatures since it is a highly viscous material under these conditions. It can, however, be transformed into a workable state by either applying heat (hot mixes), by blending with petroleum solvents (cutback mixes) or by emulsification with a surfactant in water to form a bitumen emulsion. Surface dressing is still one of the most economical and versatile surfacing options, and properly applied using advanced binders, It is potentially suitable for all classes of road. while its chippings provide a skid-resistant surface. our project includes

The specification of bitumen also shows variation with the safety, solubility, physical properties, and the durability. "Bituminous material with bitumen as a binder prepared so as to have a very high content of interconnected voids which allow passage of water and air in order to provide the compacted mixture with drain and noise reducing characteristics"

1.2 Types of Bitumen and their Properties and uses

The bitumen can be classified into the following grade types:

- • *Penetration Grade Bitumen*
- • *Oxidized Bitumen Grades*
- • *Cut Back Bitumen*
- • *Bitumen Emulsion*
- • *Polymer Modified Bitumen*

1.3.2 PENETRATION GRADE BITUMEN

The penetration grade bitumen is refinery bitumen that is manufactured at different viscosities. The penetration test is carried out to characterize the bitumen, based on the hardness. Thus, it has the name penetration bitumen.

The penetration bitumen grades range from 15 to 450 for road bitumen. But the most commonly used range is 25 to 200. This is acquired by controlling the test carried out i.e. the distillation process.

Bitumen Penetration Grade 60/70 is a standard penetration grade Bitumen usually used as a Paving Grade Bitumen suitable for road construction and for the production of asphalt pavements with superior properties. This grade of Bitumen is mainly used in the manufacture of hot mix asphalt for bases and wearing courses.

 DOI : 10.18231/2454-9150.2019.0308

1.3.3 CHARACTERIZATION OF BITUMEN

Bitumen is available in variety of types and grades. To judge the suitability of bitumen binders are most commonly characterized by their physical properties rather than its chemical properties? For engineering and construction purposes, normally three physical properties of Bitumen are important;

Consistency

Aggregates used in the pavement should be able to resist the effect caused by the jumping of the steel tyred wheels from one particle to another at different levels causes severe impact on the aggregates.

Shape of aggregates which happen to fall in a particular size range may have rounded, cubical, angular, flaky or elongated particles. It is evident that the flaky and elongated particles will have less strength and durability when compared with cubical, angular, consistency is the term used to measure its degree of stiffness ability to flow. Bitumen is thermoplastic material which means itliquefy when heatedand solidifywhen cooled and its state of solidness (stiffness) or liquidness (i.e., ability to flow)is very much temperature sensitive. Consistency of bitumen can be judged by some empirical tests such as penetration, softening point, ductility etc. and also by testing the fundamental property of bitumen such as viscosity.

Pure bitumen is completely soluble in solvents like carbon disulphide and carbon tetrachloride. Hence any impurity in bitumen in the form of inert minerals, carbon etc. could be quantitatively analysed by dissolving the samples of bitumen in any of the abovementioned solvent.

1.3.4 Safety

Bitumen materials leave out volatiles at temperatures depending upon their grade These volatiles catch fire causing a flash. The definition of flash and fire points as given by the Indian standards are as follows: The flash point of a material is the lowest temperature at which the vapour of a substance momentarily takes fire in the form of a flash under specified condition of test. The fire point is the lowest temperature at which the material gets ignited and burns underspecified conditions of test. Thus, it can be concluded that there is no point to grade bitumen on purity and safety aspect. It is the consistency property of bitumen by which it can be grade.

1.3.5Aggregates

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stresses occurring due to the wheel loads on the pavement and on the surface course they also have to resist wear due to abrasive action of traffic. These are used in pavement construction in cement concrete, bituminous concrete and other bituminous constructions and also as granular base course underlying the superior pavement layers. Therefore the properties of the aggregates are of considerable significance to the highway engineers. Origin Most of the road aggregates are prepared from: 1) Natural rock. 2) Slags derived from metallurgical process (steel plants) Gravel aggregates are small rounded stones of different sizes which are generally obtained as such from some river beds. Sand is fine aggregate from weathering of rock. The properties of the rock, from which the aggregates are formed, depend on the properties of constituent materials and the nature of bond between them.

2.1.2Desirable properties

Strength The aggregates used in top layers are subjected to (i) Stress action due to traffic wheel load, (ii) Wear and tear, (iii) crushing. For a high quality pavement, the aggregates should posses high resistance to crushing, and to withstand the stresses due to traffic wheel load.

Hardness The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. The aggregates should be hard enough to resist the abrasive action caused by the movements of traffic. The abrasive action is severe when steel tyred vehicles moves over the aggregates exposed at the top surface.

Toughness Resistance of the aggregates to impact is termed as toughness r or rounded particles of the same aggregate. Hence too flaky and too much elongated aggregates should be avoided as far as possible.

Adhesion with bitumen the aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water.

Durability The property of aggregates to withstand adverse action of weather is called soundness. The aggregates are subjected to the physical and chemical action of rain and bottom water, impurities there-in and that of atmosphere, hence it is desirable that the road aggregates used in the construction should be sound enough to withstand the weathering action

Freedom from deleterious particles Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material. Similarly aggregates used in Portland cement concrete mixes must be clean and free from deleterious substances such as clay lumps, chert, silt and other organic impurities.

2.1.3 Gradation

Porous asphalt consists predominantly of coarse aggregate, its open porous structure is advantageous for eliminating

 DOI : 10.18231/2454-9150.2019.0308

splash and spray, improving skid resistance, reducing aquaplaning potential and lowering noise level and binder content requirement. A well designed porous asphalt exhibits high porosity where pores are continuous and form a network of drainage channels. Current literature on the development of aggregate gradings show that the overriding design considerations are to produce blends that give maximum density or minimum porosity. Most of porous asphalt grading's currently specified are basedon empirical studies and do not deal directly with the packing behaviour of the aggregate mass. This paper proposes a grading for porous asphalt which is obtained by applying the theory of packing currently used to design dense bituminous mixtures. The packing behaviour of dry aggregate blends is studied using a vibratory compactor. The grading for porous asphalt is developed by applying the concept of designing to a target porosity starting with the minimum porosity of the coarse aggregate matrix. Fine aggregate grading's are varied to achieve the same target porosity. Mixes made with the gradation proposed exhibits slightly superior permeability and resistance to disintegration.

1.3.6 Demolished Concrete Waste

The global demand for construction aggregates exceeds 26.8 billion tons per year. The use of recycled aggregate in construction can be useful for environmental protection and economical terms; it started since the end of World War II by using a demolished concrete pavement as recycled aggregate in stabilizing the base course for road construction

In major cities there is a surge in construction and demolition waste (CDW) quantities causing an adverse effect on the environment. The use of such waste as recycled aggregate in concrete can be useful for both environmental and economical aspects in the construction industry. This study discusses the possibility to replace natural coarse aggregate (NA) with recycled concrete aggregate (RCA) in structural concrete.

One of the possible solutions to these problems is to recycle construction and demolition concrete waste to produce an alternative aggregate for structural concrete. Recycled concrete aggregate (RCA) is generally produced by the crushing of concrete rubble, screening then removal of contaminants such as reinforcement, paper, wood, plastics.

Construction and demolition wastes has been used as bulk filling material in road structure, well as in recycled aggregate concrete. In fine powder form, it can also be used as fillers in bituminous mixes. Some studies have indicate that performance of construction and demolition waste as sub-base material is comparable to the conventional material.

2.0MATERIALS

2.1 Choker Course

Material for the choker course and reservoir course shall meet the following:

Maximum Wash Loss of 0.5%

Minimum Durability Index of 35

Maximum Abrasion Loss of 10% for 100 revolutions, and maximum of 50% for 500 revolutions

2.1.1Filter course material

Filter course material shall have a hydraulic conductivity (also referred to as coefficient of permeability) of 10 to 60 ft/day at 95% standard proctor compaction unless otherwise approved by the Engineer. Great care needs to be used to not over compact materials. Over compaction results with loss of infiltration capacity. The filter course material is commonly referred to as a bankrun gravel In order to select an appropriate gradation, coefficient of permeability may be estimated through an equation that relates gradation to permeability,

2.1.4Filter blanket material

Filter blanket material between the filter course and the reservoir course shall be an intermediate size between the finer filter course above, and the coarser reservoir course below, for the purpose of preventing the migration of a fine setting bed into the coarser reservoir material. An acceptable gradation shall be calculated based on selected gradations of the filter course and reservoir course. A pea-gravel with a median particle diameter of 3/8" (9.5 mm) is commonplace.

2.1.5 Reservoir Coarse

Reservoir Coarse thickness is dependent upon the following criteria (that vary from site to site):

a) A 4" (10 cm) minimum thickness of reservoir course acts as a capillary barrier for frost heave protection. The reservoir course is located at the interface between sub base and native materials.

b) 4-in. (10 cm) minimum thickness if the underlying native materials are either well drained (Hydrologic Group A soils).

c) 8-in. (30 cm) minimum thickness if sub-drains are installed. Sub-drains insure that the sub base is well drained

d) Sub-drains, if included, are elevated a minimum of 4" (10 cm) from the reservoir course bottom to provide storage and infiltration for the water quality volume. If the system is lined,

e) Sub base thickness is determined from sub base materials having sufficient void space to store the design storm

 DOI : 10.18231/2454-9150.2019.0308

2.1.6 Optional Bottom Liner

Bottom Liner is only recommended for aquifer protection or infiltration prevention. This liner is to be located at the interface between sub base and native materials

IV. TESTS RESULTS

SL.NO	SAMPLE TESTED	VALUE
1.	specific gravity of given bituminous binder	0.99
2.	Ductility value of given bitumen	110mm
3.	Softening value of given bitumen	50mm
4.	Penetration value of given bitumen	63mm
5	Flash point and fire point	180 0C 240 0C
6	Aggregate Crushing Value	27.5 %
7.	Aggregate impact value	22 %
8.	Flakiness Index And Elongation Index.	12.98% and 13.91%
9.	Angularity number	**1**
10.	Specific Gravity of coarse aggregates Water absorption of coarse aggregates	**2.78** **0.5%**
11.	Bulk Density	1.60 Gm/Cc

TABLE 3.2 SIEVE ANALYSES

Sieve size(retained)	Sample 1 (gm)	Sample 2 (gm)	Sample 3 (gm)
20	228	-	-
12.5	-	162	228
10	528	-	528
9	-	297	-
6	336	635.8	336
4.7	-	97.54	-
Quarry dust	108	6.97	108

Table 3.3 Morth Specification for Bituminous Concrete of Grading

Properties of Marshall specimen	Specification limit
Marshall stability value	Min 9KN
Marshall stability value	2-4
Air void in total mix %	4
Void filled with bitumen	65-75
Void in mineral aggregate	Min 14
Height of the specimen	101.6 mm
Diameter of the specimen	63.5 mm

Table 3.4 MARSHALL STABILITY TEST

Sl.no	Binder content	Marshalll stability value (kg)	Flow value	Bulk density	%air void
1	4	734.4	2.3	24.58	2.46
2	4.5	933.3	2.7	22.59	2.97
3	5	1073.3	3.2	27.07	4.3
4	5.5	918.2	3.8	24.07	3.0
5	6	805.2	4.3	21.97	2.6

% volume of bitumen	VMA%	VFB%
10.02	12.48	70.63
10.38	13.35	73.41
11..42	15.72	76.48
11.85	14.85	78.03
12.81	15.41	79.79

V. APPLICATION

 Porous asphalt pavements have been used successfully for residential and urban streets direct run off from house can be diverted to pavement surface without allowing water into the drainage It can be used for service roads Parking lots Walkways, sidewalks, bike lanes & shoulders It can be used for roads where high traffic do not meet.

4.1 MAINTANCE In order to maintain long-term performance of porous asphalt pavements stormwater management capabilities, it is recommended that the surface infiltration rates be inspected annually during rain events to observe any changes in effectiveness of infiltrating stormwater. University of New Hampshire has created a regular inspection and maintenance guide for porous pavements (UNHSC 2011). In addition, to remove any solids and debris that could lead to more permanent

 DOI : 10.18231/2454-9150.2019.0308

clogging of the pavement, it is recommended that porous asphalt pavements be vacuumed two to four times a year.

 During winter months, there are no special requirements for plowing. Deicing chemicals may be used to melt ice and snow from the surface, but the amount of deicing chemicals will be significantly less than for impervious pavements

 Porous asphalt pavement has been serving in Italy and United States with less maintenance for more than 30years

VI. CONCLUSION

 We had done 3 mix proportion with different percentages of bitumen when compared other mix, 5% bitumen gave high strength and shall meets required porosity.

This porous asphalt pavement can be used for residential and urban streets, jogging tracks, service roads & other minor roads

 Demolished waste is used in surface course shows a satisfactory result and minimize cost of construction, that can be used for roads

 Construction of porous asphalt enhances the water table of nearby area

VII. SUMMARY AND FUTURE NEEDS

Porous asphalt pavements have been successfully used for more than 35 years in a variety of climates. They provide a pavement surface that is also part of the stormwater management system, reducing stormwater runoff and pollutants and replenishing groundwater. A number of porous asphalt parking lots have lasted more than 20 years with no maintenance other than cleaning.

Improvements have been made over the past 20 years in the design and construction of porous asphalt mixes; however, additional research should be conducted to develop improved mix-design procedures to reduce the potential for clogging and scuffing of these pavements. There is limited research on structural values for all layers of porous asphalt, therefore additional research should be conducted to determine structural values for the porous asphalt mixes and stone reservoir course.

REFERENCE

[1] Thawing", Journal of Transportation Engineering Sept/Oct: 375-381.

[2] H. Iwata, T. Watanabe, and T. Saito. 2002, "Study on the Performance of Porous Asphalt

[3] D. Newcomb, and L. Scofield. 2004, "Quiet Pavements Raise the Roof in Europe." Hot Mix Asphalt Technology, September-October, 2004, pp. 22-28.

[4] L. Schaus, S. Tighe, and L. Uzarowski, 2007 "Evaluation of Porous Asphalt Technology for Canadian Climate Use", Submitted to Transportation Research Board. Whitby, Ontario.

[5] B. Izevbekhai, and A. Akkari, 2011, Pervious Concrete Cells on MnROAD Low Volume Road. LRRB Report 2011-23, Minnesota Local Road research Board, Saint Paul, MN.

[6] Minnesota Department of Transportation. 2005 Standard Specifications for Construction,

[7] National Asphalt Pavement Association (NAPA), 2003, Porous Asphalt Pavements, NAPA

[8] R. Mallick, P. Kandhal, A. Cooley, and D. Watson. 2000. Design, Construction and Performance of New Generation Open-Graded Friction Courses. National Center for Asphalt Technology Report 00-01. NCAT, Auburn, AL.

[9] R. J. Rohne, and M. A. Lebens, Subgrade Temperatures and Freezing Cycles in Pervious Pavements. Minnesota Department of Transportation, 2009, Saint Paul, MN.

[10]Cahill, T. H., Adams, M., &Marm, C. (March–April 2005). Stormwater Management with Porous Pavements.Government Engineering, 14–19. Retrieved from http://www.smscland. org/pdf/PorousCahill.pdf.

[11] Hall, G. (n.d.). Winter Maintenance Guidelines for Porous Pavements.University of New Hampshire StormwaterCenter.Retrievedfrom http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/winter_maintenance_fact_sheet.pdf.

[12]Hansen, K. R. (2008). Porous Asphalt Pavements for Stormwater Management. Report IS 131. National Asphalt Pavement Association.

[13]Hein, D. K., Strecker, E., Poresky, A., Roseen, R. M., &Venner, M. (2013). Permeable Shoulders with Stone Reservoirs. NCHRP Project 25-25, Task 82. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/docs/ NCHRP25-25(82)_FR.pdf.

[14]Houle, J. J., Roseen, R. M., Ballestero, T. P., Puls, T. A., &Sherrard Jr., J. (2013). Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional StormwaterManagement.Journal of Environmental Engineering, 139(7), 932–938.

[15] Lebens, M. (2012). Porous Asphalt Pavement Performance in Cold Regions. Report 2012-12. Minnesota Department of Transportation. Retrieved from http://www.dot.state.mn.us/research/documents/201212.pdf.

 DOI : 10.18231/2454-9150.2019.0308