Experimental Investigation and Estimation of Low Cost Pavements in Roads for Storm Water Management

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Abstract

As the cities grow, the number of impermeable surfaces those that do not allow water to infiltrate into the ground can increase. Managing runoff in urban areas becomes difficult and forms flooding. If it is not properly maintained, the storm water runoff forms the negative effect on nearby surface water. The implementation of the permeable pavement increases the infiltration rate of water into the ground surface and also increases the filtration of rain water. This will be difficult to find the cost-effective pavement by hydrological assumptions and also the installation of permeable pavement is costly than compared to the impermeable pavements. Even though it is costlier, it gives higher benefits and improves the water sustainability. This paper gives the estimation of suitable cost effective permeable pavement for the selected site in K. K. Nagar, Trichy.

Keywords- Storm Water Management, Cost Analysis, Porous Asphalt Pavement, Ground Water Recharge, Urban Roads

I. INTRODUCTION

Nowadays the urbanization increases. Due to the increase in urbanization, storm water runoff gets reduced. It leads to stagnation of storm water instead of infiltrating into the ground and also causes flooding in that area. To rectify this problem, the permeable pavement is the only way to reduce flooding and increases the ground water table. There are several mIethods of storm water management as well as permeable pavement. By analyzing and providing the cost-effective pavement gives Best Management Practice (BMP) and low impact development. The use of open graded aggregate increases the void spaces; thus the storm water penetrates into the pavement to the soil. When it is properly installed and maintained, it gives the effective storm water management. These pavements have high porosity because of large aggregates with no fine aggregates. As the water drains through the porous and into the stone bed, it slowly infiltrates into the soil, Recharge and Replenish Ground Water Level. Extended Pavement Life Due to Well Drained Base and Reduced Freeze-Thaw.

By analyzing the cost-effective pavement, we will provide the pavement at a selected site in K.K.Nagar, Trichy. And give the best estimate for the suitable pavement.

II. SITE SELECTION

Site selection is the important factor for providing permeable pavement. The site should be selected for permeable pavement based on the permeability of soil, infiltration rate, depth to bedrock, depth to water table, etc. These data can be taken from past investigation or test on bore pits. We selected the site based on these requirements as K.K.Nagar, Trichy. The max of monthly rainfall can be taken out from the past monthly rainfall data. The monthly rainfall data collected for the period from 1997 to 2017. -Max. Rainfall of 858.2 mm occurred in August 2005-2006 (data from Agricultural Department, Trichy).

1) Soil type: Red loamy soil. (Silty clay loam, sandy clay, silty clay, clay soil is the only soil not adopted for permeable pavement. Because it has the infiltration rate with less than 0.5 in/hr.)

2) Infiltration rate: 0.8 inch/hr. (The minimum infiltration rate for the soil must be greater than 0.27in/hr for the application of permeability).Thus, the selected site is suitable for the laying of permeable pavement.

III. TYPES OF PERMEABLE PAVEMENT

There are several types of porous pavements are available based upon their climatic conditions. In India, three types of pavements are predominantly used to satisfy the needs. They are

1) Pervious Concrete,
2) Plastic Grids,
3) Porous Asphalt,
4) Single- Sized Aggregates,
5) Porous Turf,
6) Permeable Interlocking Concrete Pavements,
7) Permeable Clay Brick Pavements,
8) Resin Bound Paving

1) Pervious Concrete

Pervious concrete is mostly available, and it can bear the frequent traffic and it is easily accessible. Pervious concrete quality is depending on the installer's knowledge and experience.

2) Plastic Grids

Plastic grids allow for 100% porous system using structural grid system for containing and stabilizing either gravel or turf. These grids come in a variety of shapes and sizes depending on use. It is used for pathways and commercial lots. These systems have been used readily in Europe for over a decade but are gaining popularity in North America due to requirements by government for many projects to meet LEED building standards.

3) Porous Asphalt

Porous asphalt is prepared and laid using the methods same as in traditional asphalt pavment. The difference is the fine aggregates are excluded from the asphalt mix and the remaining large same – sized aggregate particles have open pores that give the porosity and permeability properties of the materials.

By adding the fiber into the mixture or a polymer-modified binder (PG 76 - 22 PM) may be used to check the pavement strength. Generally, the water drains through the porous, into the stone bed and it slowly infiltrates into the soil, Recharge and Replenish Ground Water Level.

Open-graded friction courses (OGFC) are a pervious asphalt pavement course used on highways to improve the safety of travelers by drain water from the wearing course. OGFC don't drain water directly to the ground. But, they allow water to infiltrate the top 0.75 to 1.5 inch deph of the pavement and then drain out to the side of the pavement. It is used to improve the friction properties of the road and then reducing the usage of road spray.

4) Single- Sized Aggregates

Single – sized aggregates without using any binder. E.g. loose gravel, single chipping is other alternative. Even though it can only be safely used for low speed and low traffic setting. For example: Car parking and drives. It has high potential cumulative area.

5) Porous Turf

Porous turf, at properly constructed state, which can be used for temporary parking utilities at shops and stadia. Plastic turf reinforcing grids are additionally be used to transfer the load, which are not considered in design.

6) Permeable Interlocking Concrete Pavements

These concrete paver blocks are concrete blocks with open and permeable spaces between the blocks. They produce good architectural view and can withstand both light and medium traffic, especially interlocking concrete pavers, except the high-volume roads or else high speed roads. Some products are polymer-coated pavers and have an porous surface.

7) Permeable Clay Brick Pavements

These pavements are fired clay brick units with open, permeable spaces between the units. Clay pavers provide a durable surface that allows storm water runoff to permeate through the joints.

8) Resin Bound Paving

It is a mixture of both resin binder and aggregate. Pure resin is used to before laying-off, fully coat each aggregate particle. To permit each aggregate particle to stick to each other and to the base leave voids for penetrate the water through by using limited resin. Resin bound paver provides a durable surface and strong. It is suitable for pedestrian and many applications such as pathways, driveways, etc.

IV. COST ANALYSIS

From the above permeable pavements, the pervious concrete, porous asphalt and pavers are mostly suitable for the Indian climate. So we are taken into considerations for cost analysis.

A. Materials used for Pervious Concrete

- Mixture of Portland cement
- Coarse aggregate or gravel
- Water

Void ratio- 15-35%

Quantity for 100m Length&10m Width

Description of work	*Length(m)*	*Breadth(m)*	*Depth(m)*	*Quantity(m^3)*
Pervious paving course	*100*	*10*	*0.16*	*160*

Materials used for porous asphalt pavement

Mixture of both fine and coarse aggregate together with bitumen binder.

Void ratio- 15-35%

Quantity for 100m Length&10m Width

Description of work	*Length(m)*	*Breadth(m)*	*Depth(m)*	*Quantity(m^3)*
Hot Mix Asphalt	*100*	*10*	*0.152*	*152*
Stone aggregate	*100*	*10*	*0.152*	*152*

Abstract of cost analysis

Quantity of materials per m^3 for pervious concrete	*Quantity of materials for $160m^3$ of pervious concrete pavement*
Cement : 540 kg/ m^3	*Cement : 86400 kg*
Coarse aggregate : 1746 kg/ m^3	*Coarse aggregate : 279360 kg*
Water : 186 kg /m^3	*Water : 29760 kg*
Silica fume : 60 kg/ m^3	*Silica fume : 9600 kg*

B. Cost of Materials used in Pavement

Cement: 4391/MT

Coarse aggregate (13.2 mm): 1378.25/cu.m

Water: 130/KL

Silica fume: 17250/MT

63 mm aggregate: 1059.07/cu.m

Bitumen: 26300/MT 385572902.4

Total Cost

For pervious concrete pavement: Quantity * Rate = Rs. 385572902.4

For asphalt pavement: Quantity * Rate = Rs. 9684880.64

C. Conclusion of Cost Analysis

From the above estimate, we conclude that the porous asphalt pavement has cost effective than the previous pavement and paver blocks. Thus, we design the porous asphalt pavement for the selected site.

Design of Asphalt pavement

Materials for asphalt pavement

Geo-textile

Non-woven (Place on uncompacted sub grade)

Aggregate Bases

Reservoir Course (2" to 3" size)

Choker Course (1/2 "size)

Hot Mixed Asphalt

Asphalt Treated Permeable Base (ATPB)

Open-Graded Wearing Course

Binder: Polymer modified binder (PG 76 - 22 PM)

Calculated dimensions of roads

The selected site contains different width of roads. Thus, we are classified into three types of roads depending upon the dimensions.

Road lengths	*Road widths*
Class A = 2.645 km	*Class A = 30m*
Class B = 8.648 km	*Class B = 7.6m*
Class C = 62.54 km	*Class C = 4.4m*

Estimation of Asphalt pavement

Table 1: Detailed Estimate for Forming of Asphalt Pavement

Sl. No	*Description of work*	*Nos*	*L(m)*	*B(m)*	*D(m)*	*Quantity(m^3)*
1	*Dismantling the existing roads and excavation of earth*					
	For "A type" roads - 30m breadth	*1*	*100*	*30.00*	*1*	*3000*
	For "B type" roads - 7.6m breadth	*1*	*100*	*7.60*	*1*	*760*
	For "C type" roads - 4.4m breadth	*1*	*100*	*4.40*	*1*	*440*

2	Conveyance charges for excavated soil					
	For "A type" roads - 30m breadth	1	100	30.00	1	3000
	For "B type" roads - 7.6m breadth	1	100	7.60	1	760
	For "C type" roads - 4.4m breadth	1	100	4.40	1	440
3	Filling the excavated portion up to the required depth for forming the new pavement using gravel					
	For "A type" roads - 30m breadth	1	100	30.00	0.436	1308
	For "B type" roads - 7.6m breadth	1	100	7.60	0.436	331.36
	For "C type" roads - 4.4m breadth	1	100	4.40	0.436	191.84
4	Spreading gravel for the sub grade					
	For "A type" roads - 30m breadth	1	100	30.00	0.25	750
	For "B type" roads - 7.6m breadth	1	100	7.60	0.25	190
	For "C type" roads - 4.4m breadth	1	100	4.40	0.25	110
5	Providing the non-woven Geo textile membrane using the thickness of 0.01 m					
	For "A type" roads - 30m breadth	1	100	30.00	0.01	30
	For "B type" roads - 7.6m breadth	1	100	7.60	0.01	7.6
	For "C type" roads - 4.4m breadth	1	100	4.40	0.01	4.4
6	Required number of non-woven geo textile road					
	For "A type" roads - 30m breadth	1	(100 * 30)/ 49.52			60.58
	For "B type" roads - 7.6m breadth	1	(100 * 7.6)/ 49.52			15.34
	For "C type" roads - 4.4m breadth	1	(100 * 4.4)/ 49.52			8.88
7	Providing 63 mm aggregate including cost of materials, conveyance and labour charges etc.					
	For "A type" roads - 30m breadth	1	100	30	0.152	456
	For "B type" roads - 7.6m breadth	1	100	7.6	0.152	115.52
	For "C type" roads - 4.4m breadth	1	100	4.4	0.152	66.88
8	Laying of Hot Mix Asphalt (HMA) concrete using 13.2 mm aggregate including cost of materials, conveyance and labour charges etc.					
	For "A type" roads - 30m breadth					
	(i) Rectangular surface	1	100	30	0.152	456
	(ii) Triangular surface	2	100	1/2 * 30 * 0.47		1410
				Total		1866
	For "B type" roads - 7.6m breadth					
	(i) Rectangular surface	1	100	7.6	0.152	115.52
	(ii) Triangular surface	2	100	1/2 * 7.6* 0.12		91.2
				Total		206.72
	For "C type" roads - 4.4m breadth					
	(i) Rectangular surface	1	100	4.4	0.152	66.88
	(ii) Triangular surface	2	100	1/2 * 4.4*0.0.07		30.8
				Total		97.68
9	Charges for soil test			LS		2000

Table 2: Cost of Materials at Site

Item. No	Name of materials	Lead in Km	cost at quarry	Unit	Conveyance	stacking charges	Total
1	63 mm metal	80	556.19	m^3	563.51	3.15	1123
2	13.2 mm metal	80	1178.1	m^3	563.51	3.15	1745
3	Gravel	7	174.29	m^3	82.44	3.05	259.8
4	Bitumen(cost at site)	7	29550	MT			29500
5	Non-woven Geo textile(1 roll = 49.52 m^2)	7	204	roll			4.12

Table 3: Schedule of Rates

1	Earth work SS 20 A	Cum	61.65
2	Power roller/Road Roller	Day	788.57
3	Water sprinkler	Day	1103.81
4	Stacking gravel	Cum	3.05
5	Diesel		47.08
6	Refilling (Earth)		20.27
7	Mazdoor Grade I	Day	364.58
8	Mazdoor Grade II	Day	326.7

Table 4: Abstract of Estimate for the Proposed Asphalt Pavement

Sl.no	Quantity			units	Description of work	Rate	per	Amount/ 100 m		
	A	B	C					A	B	C

1	*3000*	*760*	*440.00*	*m^3*	*Dismantling the existing roads and excavation of earth*	*123.30*	*m^3*	*369900.00*	*93708.00*	*54252.00*
2	*3000*	*760*	*440.00*	*m^3*	*Conveyance charges for the excavated soil*	*123.30*	*m^3*	*369900.00*	*93708.00*	*54252.00*
3	*1308*	*331.4*	*191.84*	*m^3*	*Filling the excavated portion upto the required depth for forming the new pavement using gravel*	*283.10*	*m^3*	*370294.80*	*93808.02*	*54309.90*
4	*750*	*190*	*110.00*	*m^3*	*Spreading gravel for the sub grade*	*283.10*	*m^3*	*212325.00*	*53789.00*	*31141.00*
5	*30*	*7.6*	*4.40*	*roll*	*Spreading and aligning of Non-woven Geo textile of size 50m * 1m*	*221.60*	*roll*	*6648.00*	*1684.16*	*975.04*
6	*456*	*115.5*	*66.88*	*m^3*	*Provision of 63 mm agg. including cost of materials , conveyance and labour charges*	*2285.88*	*m^3*	*1042361.28*	*264064.86*	*152879.65*
7	*1866*	*206.7*	*97.68*	*m^3*	*Laying of Hot Mix Asphalt(HMA) concrete using 13.2 mm aggregate including cost of materials , conveyance and labour charges*	*5809.10*	*m^3*	*10839780.60*	*1200857.15*	*567432.89*
					TOTAL			*13211209.68*	*1801619.19*	*915242.49*

Table 5: General Abstract of Estimate for the Proposed Asphalt Pavement

Sl.no	*Length*	*unit*	*Description of work*	*Rate/100 m*	*Per*	*Amount*
1	*2061.00*	*m*	*Abstract for the proposed Asphalt Pavement*	*13211209.68*	*m^3*	*272283031.50*
2	*9905.00*	*m*	*Conveyance charges for the excavated soil*	*1801619.19*	*m^3*	*178450380.77*
3	*57777.00*	*m*	*Filling the excavated portion upto the required depth for forming the new pavement using gravel*	*915242.49*	*m^3*	*528799653.45*
4	*LS*		*cost for soil test*	*LS*		*2000.00*
				Total		*979535065.72*

V. CONCLUSION

From this investigation and analysis pervious pavements are the alternative for common asphalt pavement. Permeable pavements can be a major contributor to the effective management of storm water. They provide the opportunity of transforming a traditional source of storm water runoff into a best management practice for capturing, storing and infiltrating storm water into the natural surroundings. Benefits achieved include reduced storm water discharges as well as improvements to water quality including reduced suspended solids and reduction of chemical contaminants. While they can be an effective tool, their design and construction should carefully consider structural and hydrological concerns to ensure that they provide cost-effective solutions over their design life. The overall cost of the pervious asphalt pavement during its design period is lower than the traditional pavement. And also has another advantage as low maintenance cost.

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