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Comparative Study of Porous and Non-Porous Rigid Pavement

Jaimin J Solanki, Prof. Vrundani Vaidya
Department of Civil Engineering, Hasmukh Goswami College of Engineering, Ahmedabad, Gujarat, India

ABSTRACT

This research work represents the experimental work related comparison of porous pavement and rigid pavement. Nowadays porous pavement is a new concept introduced worldwide. There are many advantages of porous pavement. 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 and environmentally friendly. This study tries to evaluate the benefits of the Porous pavements and comparing it with the other rigid pavement. For this Purpose, various types of tests carried out on regarding soil base layer which are compressive strength, Flexure strength, Split Tensile test and Infiltration rate Test From the analysis of the data, type of the soil which is suitable for the porous pavement is carried out. And mix design is also done for the concrete.
Keywords: Porous Pavement, Compressive Strength Test, Flexure Strength Test, Split Tensile Test and Infiltration Rate Test.

I. INTRODUCTION

Increased urbanization causes pervious green fields to be converted to impervious areas increasing storm water runoff. Engineers and scientists have combined their knowledge to introduce innovative thinking to manage the quality of urban runoff and harvest storm water for productive purposes. With increased population and climate change water shortage problems are troubling mankind all over the world. How to harvest the water during rainfall events for use at times of need is of major interest subject to civil engineers, environmentalists and to the community. On the other hand, with urbanization, more impervious road and roof surfaces appear resulting in increased runoff from rainfall. Most of the floods occur because existing drainage systems are unable to handle peak flows during rainfall events. During a storm event, flood runoff will carry contaminants to receiving waters such as rivers and Creeks. There is increased interest in protecting river water quality and as a result, improving the quality of storm water. A porous asphalt pavement differs from traditional asphalt pavement designs in that the structure permits fluids to pass freely through it, reducing or controlling the amount of run-off from the surrounding area. By allowing precipitation and run-off to flow through the structure, this pavement type functions as an additional storm water management technique. The overall benefits of porous asphalt pavements may include both environmental and safety benefits including improved storm water management, improved skid resistance, reduction of spray to drivers and pedestrians, as well as a potential for noise reduction. Applying permeable pavements as an alternative to traditional drainage systems should be extended, especially in dry regions in order to recharging groundwater.

Objective and Scope of Study

Objectives

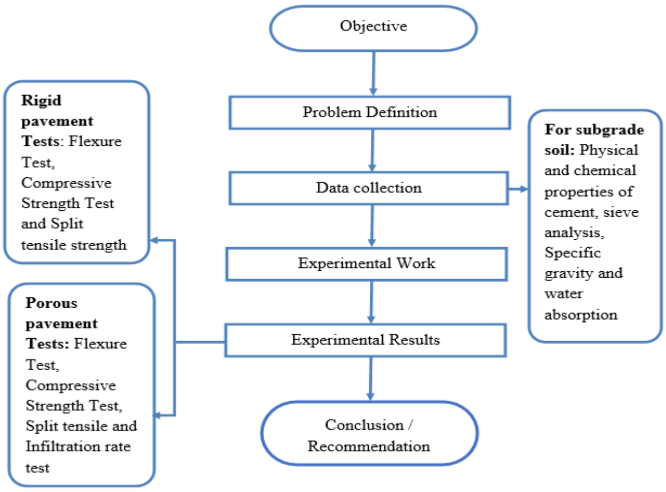
- To design porous pavement and rigid pavement as per design standards.
- To evaluate the performance of porous pavement by comparing it with conventional rigid pavement.

Scope

- To evaluate the properties of porous and non-porous rigid pavement by its strength, flexure and porosity.

II. METHODS AND MATERIAL

Methodology



Mix Design

Design Stipulation:

Grade of Concrete : M-30

Characteristic compressive strength : 30 N/mm^2

Maximum Nominal Size of Aggregate :20 mm (Angular)

Workability degree : 0.92 Compacting Factor

Degree of Quality control : Good

Type of Exposure (IS-456:2000, Table-5): Moderate

Test Data for Materials:

Cement Used		OPC 53 Grade Conforming to IS 8112
Specific Gravity of Cement		3.15
Specific Gravity of Aggregates:		
1.	Coarse Aggregates	2.90
2.	Fine Aggregates	2.86
Water Absorption:		
1.	Coarse Aggregates	0.86%
2.	Fine Aggregates	0.98 %
Free (Surface) Moisture:		
1.	Coarse Aggregates	Nil
2.	Fine Aggregates	Nil

Step 1: Target Strength for Mix Proportion of concrete

f_{ck} ‘ $= f_{ck} + (1.65 \text{ x } s)$

$= 30 + (1.65 \text{ x } 5)$

$= 38.25$ N/mm^2

where,

f_{ck} ‘= Target Average Compressive Strength at 28 Days

f_{ck} = Characteristic Compressive Strength at 28 Days

s = Standard Deviation

The value of s is taken from table 1 of IS: 10262-2009; for M-30, s = 5

Step 2: - Selection of Water Cement Ratio

According to IS 456-2000 (Table 5, Page No. 20), for moderate condition maximum water-cement ratio = 0.45.

Step 3: - Selection of Water Content:

From Table 2, IS: 10262-2009, for 20 mm Aggregate,

Maximum Water Content = 186 litre

Hence, Estimated Water Content = 186 + (3% of 186) = 191.61 litre

Step 4: - Calculation of Cement Content: w/c Ratio: 0.45

Hence, Cement Content = 191.61 / 0.45 = 425.8 kg / m3

From Table-5 of IS: 456-2000, minimum cement content for moderate exposure condition is 300 kg / m^3

425.8 kg / m3 > 300 kg / m3, hence, O.K.

Step 5: - Proportion of Volume of Coarse Aggregate and Fine Aggregate Content:

From Table-3 of IS: 10262-2009, Volume of Coarse Aggregate corresponding to 20 mm aggregate and fine aggregate (Zone II) for water-cement ratio of 0.45 is 0.62. In the present case water-cement ratio is 0.45. Therefore, Volume of Coarse Aggregate is not required to be increased/decreased to decrease/increase the fine aggregate content. The proportion of Volume of Coarse Aggregate is increased/decreased by 0.02 (at the rate of - /+ 0.01 for every ± 0.05 change in water-cement ratio).

(NOTE - In case the coarse aggregate is not Angular one, then also volume of coarse aggregate may be required to be increased suitably, based on experience. For Pumpable Concrete these values should be reduced by 10 percent.)

Therefore, **Volume of Coarse Aggregate = 0.62 (62%)**

Volume of Fine Aggregate = 1 - 0.62 = 0.38 (38%)

Mix Calculations:

1. Volume of Concrete = 1 m3

2. Volume of Cement = (Mass of Cement / Sp. Gravity of Cement) * (1/1000) = (425.8/3.15) * (1/1000) = 0.135 m3

3. Volume of Water = (Mass of Water / Sp. Gravity of Cement) * (1/1000) = (191.61/1.00) * (1/1000) = 0.192 m3

4. Volume of all in Aggregate = [1 – (0.135+0.192)] = 0.673 m3

5. Mass of Coarse Aggregate = 0.673 * 0.62 * 2.90 * (1000) = 1210.05 kg / m3

6. Mass of Fine Aggregate = 0.673 * 0.38 * 2.25 * (1000) = 731.42 kg / m3

Mix Proportion:

	Water	Cement	Fine Aggregate	Coarse Aggregate
By Weight [kg / m^3]	**191.61**	**426**	**731.42**	**1210.05**
By Volume	**0.50**	**1**	**1.72**	**2.84**

Mix Design of pervious concrete:
As per ACI design procedure followed and given below:

Step 1: Determination of coarse Aggregate (W_a)

Stone with no fine aggregate ACI table 6.1 recommends b/b_0 of 0.99, with dry-robbed density given as 1450 kg/m^2

W_a = dry rotted density / (b/b_0)

W_a = 1450 x 0.99

= 1436 kg (Dry weight)

Step 2: Adjust to ssd Weight (W_{ssd})

W_{ssd} = W_a x water absorption on Aggregate

W_{ssd} = 1436 x 0.86

= 1235 kg (ssd)

Step 3: Determination of paste Volume (V_p)

ACI table 6.3 and read along the required percentage voids (40% for this example) to the well compacted curve. Then read down to find the paste percentage at 30% of a cubical yard is 8.10 ft^3

Thus, V_p = 8.10 ft^3

Step 4: Determination of Cement content (C)

C = {Vp / (0.315 × water cement ratio)}x 1000

C = {(8.10/35.314) / (0.31 × 0.45)} x 1000

= 303 kg

Step 5: Determination of Water content (W)

W = Cement x Water cement ratio

= 330 x 0.45

= 136.35 kg

Step 6: Determination of Solid Volume (V_s)

Aggregate volume (V_a) = W_{ssd} / (Specified gravity of coarse aggregate * 1000) = 1235 / (2.90 x 1000) = 0.426 m^3

Cement volume (V_c) = {c/ (Specific gravity of cement* 1000} = {303 / (3.15 x 1000)} = 0.096 m^3

Water Voume (V_w) = (W/1000)

= 136.35 /1000

= 0.136 m^3

Total solid volume (V_s) = $V_a + V_c + V_w$

= 0.426 + 0.096 + 0.136

= 0.658

Step 7: Determination of Percentage of voids (P_s)

Percentage of voids (P_v) = ($V_{wt} – V_s$)/V_{wt} x 100

= (1 – 0.658)/1 x 100

= 34.2 %

Step 8: Iterative Trail Batching and Testing

The trail batch weight as per cubic meter as per follows:

Cement = 303 kg

Water = 136 kg

Coarse Aggregate = 1235 kg (ssd)

Total weight = 1674 kg

III. RESULTS AND DISCUSSION

Compressive Strength Test [Is: 516-1959]

For conventional concrete

Cube Ref. Number	Age at Test	Load (KN)	Compressive strength N/sq.mm	Avg. at age of testing
1	07 days	920.0	40.89	40.70
2		918.0	40.80	
3		909.0	40.40	
1	28 days	1110.0	49.33	49.19
2		1090.0	48.44	
3		1120.0	49.78	

For Pervious concrete

Cube Ref. Number	Age at Test	Load (KN)	Compressive strength N/sq.mm	Avg. at age of testing
1	07 days	314.0	13.96	14.01
2		302.0	13.42	
3		309.0	13.73	
1	28 days	478.0	21.24	22.52
2		496.0	22.04	
3		502.0	22.31	

Flexure Strength Test

For conventional concrete:

Sr. No	Identified as	Flex. Load (kN)	Flex. Strength (N/mm²)	Avg. Flex. Strength (N/mm²)	Requirement As per IS per 516:1959
1	1/3	32.55	5.78	5.2	4.4 Min.
2	2/3	26.92	4.79		
3	3/3	28.76	5.11		

For Porous concrete:

Sr. No	Identified as	Flex. Load (kN)	Flex. Strength (N/mm²)	Avg. Flex. Strength (N/mm²)
1	1/3	12.10	2.15	2.28
2	2/3	12.80	2.28	
3	3/3	13.50	2.40	

Split Tensile Strength Test

For conventional concrete

Cube Ref. Number	Age at Test	Load (KN)	Split tensile strength N/sq.mm	Avg. at age of testing
1	07 days	390.0	5.52	5.49
2		389.0	5.51	
3		386.0	5.45	
1	28 days	471.0	6.66	6.64
2		462.0	6.54	
3		475.0	6.72	

For Porous concrete

Cube Ref. Number	Age at Test	Load (KN)	Split tensile strength N/sq.mm	Avg. at age of testing
1	07 days	133.0	1.88	1.85
2		128.0	1.81	
3		131.0	1.85	
1	28 days	203.0	2.87	2.95
2		210.0	2.98	
3		213.0	3.01	

Infiltration Test Result:

Time reading on the stopwatch during infiltration = 92 sec

Weight of the water = 18 kg
= 40 lbs.

Calculations:

M (Water Mass) = 18 kg

D (Diameter of Infiltration Ring) = 12 Inch

T (Time to infiltration) = 92 Sec

K (constant) = 126,870 inch

$$I = \frac{K \times M}{D^2 \times t} = \frac{126{,}870 \times 40}{12^2 \times 91}$$

= 383.06 Inch/hr.

= O.K. (Infiltration rate should be in between 100 to 550 inch/hr as per ASTM 1701)

IV. CONCLUSION

Mix design of both conventional and porous concrete has been done for comparison. From the data it is concluded that the concept of the porous pavement is applicable for the low volume water logged area. Porous concrete, porous asphalt and interlocking concrete paver block are the best solutions in that type of area.

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