IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
ISSN : 2278-1684, Volume 3, Issue 1, (Sept.-Oct. 2012), PP 67-69
www.iosrjournals.org

Characteristics of Porous Concrete Media

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Abstract: *In towns and big cities, the storm water overflow causes many problems like temporary flooding when it is not effectively managed. Indian towns and bigger cities are growing at a faster rate from last few decades due to educational, employment and business opportunities available in towns and bigger cities. The urbanization and concentration of population has increased requirement of buildings and other facilities. This results in increase in impervious surfaces which resulted in increased surface runoff and decrease in rainwater percolation in soil. The problems of managing storm water are becoming more and more severe due to increased storm water runoff. The stormwater overflow is routed through the combined sewers to the treatment plants which eventually increase in the quantity of wastewater, cost for pumping and treatment. Therefore the management of stormwater is one of the important challenges with the municipal authorities. The porous pavement systems are a unique way of handling and treating stormwater under such conditions. This paper highlights the material requirement, properties, construction process, benefits and limitations of porous concrete.*
Keywords: *Concrete, Management, Porous Pavement, Runoff, Stormwater.*

I. Introduction

During last few decades the construction industry has seen a multifold growth which has eventually lead to decrease in effective open land, and therefore, reducing the amount of stormwater to percolate inside the ground. The conversion of open soil pervious surfaces to concrete and other impervious surfaces resulted in increased runoff rate and total volume of stormwater, reductions in groundwater recharge and evapotranspiration. In urban areas the management of stormwater is one of the major challenges with the municipal authorities. To increase the ground water infiltration and to effectively manage the excess storm water, opting for porous surface media is one of the methods. This porous surface media for pavement layer is capable of supporting the light traffic. It has a detention layer which consists of gravel or crushed stone with sufficient voids to allow stormwater to collect and infiltrate into the soil beneath. Porous pavement systems minimize stormwater overflow and recharge local groundwater levels.

II. Definitation

"As per American Concrete Institute (ACI 522R-10, Report on Porous Concrete, 2010) the term 'porous or porous concrete' typically describes a near zero-slump, open-graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water".

III. Materials Properties

The mixture of cement, coarse aggregate, and water will produce a hardened concrete with interconnected pores. These interconnected pores will allow the stormwater to pass through them easily. The size of interconnected pores ranges from 2 mm to 8 mm. The aggregate grading used in porous concrete is typically either single-sized coarse aggregate or grading between 10 and 20 mm. The void content can range from 15 to 35%, but most desired porosity is about 20%. Porous concrete can be made with or without chemical admixtures. In general the retarding admixtures or viscosity modifying agents are used for obtaining desired properties. Supplementary cementitious materials such as fly ash, silica fume, ground granulated blast furnace slag (GGBFS) can also be added or partially replaced with cement for making porous concrete. However, the desired properties of the porous concrete like, porosity, compressive strength, and permeability should achieved in presence of Supplementary cementitious materials whether these are added or partially replaced with cement in producing porous concrete. The following procedure is suggested by ACI to obtain mix proportioning of porous concrete:

1. Determine aggregate weight
2. Adjust to saturate surface dry weight
3. Determine required paste volume
4. Determine cement or cementitious content
5. Determine water content
6. Determine solid volume

7. Check void content, and
8. Iterative trial batching: Test for required properties, and Adjust mixture proportions until the required performance is achieved

The plastic porous concrete mixture is stiff compared to traditional concrete. Following are the properties of porous concrete:

- Slump: < 20 mm.
- Density: 1600 kg/m3 to 2000 kg/m^3.
- Compressive strength: 3.5 MPa to 28 MPa (suitable for a wide range of applications).
- Infiltration rate: 80 to 720 litres per minute per square metre.

A moderate porosity of porous concrete pavement system will typically have a permeability of 140 litres per minute per square metre (i.e. 8400 mm/hr). However, no record of such heavy rainfall is available. In contrast the steady state infiltration rate of soil ranges from 25 mm/hr and 0.25 mm/hr. This clearly suggests that unless the porous concrete is severely clogged up due to possibly poor maintenance it is unlikely that the permeability of porous concrete is the controlling factor in estimating runoff (if any) from a porous concrete pavement.

IV. Typical Mix Proportioning

A typical proportion of different ingredients are shown in Table no. 1. For a particular type of available material the mix design will depend on properties of the individual ingredients. To arrive at a proper mix all the materials must be must be tested for physical properties. Trails on the designed mix proportions should be carried out to verify the expected behaviour. One has to carefully verify the mix proportions for pervious concrete to get optimal results of performance with available local materials.

Table 1. Typical Ranges of Materials Proportions

Description	**Proportions**
Cementitious materials	250 to 325 (kg/m^3)
Total Aggregate	1150 to 1500 (kg/m^3)
Fine aggregate	0 to 300 (kg/m^3)
Water/cementitious material ratio	0.27 to 0.36

V. Construction Process

Proper subgrade preparation is important and it should be well compacted to provide a uniform and stable surface. If the porous concrete pavement is placed directly on gravelly soils or on sandy soils it is necessary to compact the subgrade to 95% of the maximum density (ASTM D 1557). For silty soil or clayey soils, the compaction level depends on the pavement design. It may be required to put a layer of open graded stone over the soil. Sometimes engineering fabrics are used so as to separate fine grained soils from the stone layer. It is recommended that the subgrade should be moistened before the concrete placement. This will prevent the porous concrete from setting and drying. Process of rolling will consolidate the fresh concrete to provide strong bond between the cement paste and coarse aggregate. This will eventually provide a smoother riding surface. Proper curing is essential to the structural integrity of a porous concrete pavement. Curing should begin within 20 min after final consolidation and continue through 7 days.

VI. Maintenance of Porous Concrete Pavement

Maintenance of porous concrete pavement consists primarily of prevention of clogging of the void structure. There are two commonly accepted maintenance methods. First one is by pressure washing, and another is power vacuuming. The application of pressure, forces the contaminants downwards through the pavement surface thereby removing the entire clog. Power vacuuming removes contaminants by extracting them from the pavement voids. The most effective way of maintenance is to combine both the techniques by following the sequence of power vacuum after pressure washing.

VII. Applications of Porous Concrete

Porous concrete can be used in roads around the buildings and the surfacing inside the compound. The most preferable application of porous concrete pavement is all around the buildings and in the open parking areas. Porous concrete pavement may be used in construction of highway median for stormwater runoff mitigation. There may be other application for its use as a surface material to reduce hydroplaning, splash and spray, and mitigate tire-pavement noise. The following are some of the major applications of porous concrete in dealing with storm water runoff management:

- Parking lots
- Low-volume roads
- Road shoulders
- Sidewalks
- Service roads
- Gullies
- Driveways
- Courtyards
- Median construction

VIII. Limitations of use of Porous Concrete

Innovations in porous concrete mixtures and techniques of placement have made it a very feasible choice for management of stormwater. Casting of porous concrete differs from the conventional concrete pavement. If significant care is taken to produce porous concrete it gives good results. Codal provision on specifications, applications, and constructing techniques are continually evolving and are being published in international codes.

IX. Conclusions

The application of porous concrete to efficiently manage stormwater runoff will be reduce the burden on waste water treatment carried out by municipal authorities. The porous pavement systems are a unique way of handling and treating stormwater. The porous concrete allows water to percolate through the purposely created voids in concrete. Based on the above applications of porous concrete, the following conclusions can be drawn:

- Porous concrete pavement can be used to substantially reduce the volume of runoff, to provide ground water recharge and to reduce pollutants in storm water runoff.
- Porous pavement systems can fetch 75% of annual rainfall going toward ground water recharge.
- Porous concrete pavement is very effective in removal of pollutant load, in some cases demonstrating greater than 80% efficacy in pollutant removal.
- Stormwater management systems can be effective in long term savings.
- Porous pavements were extremely effective at managing storm water and filtering impurities.

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