iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: IV Month of publication: April 2023

DOI: https://doi.org/10.22214/ijraset.2023.49948

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

Applications of Pervious Concrete in Road Pavements

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Abstract: Pervious concrete is a relatively new concept for rural road pavement, with increase into the problems in rural areas related to the low ground water level, agricultural problem. Pervious concrete has introduced in rural road as a road pavement material. Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater level and minimize storm water runoff. This introduction to pervious concrete pavements reviews its applications and engineering properties, including environmental benefits, structural properties, and durability. In rural area cost consideration is the primary factor which must be kept in mind. So that in rural areas costly storm water management practices is not applicable. Pervious concrete pavement is unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground. This pavement technology creates more efficient land use by eliminating the need for retention.

I. INTRODUCTION

A. General

Pervious concrete pavement is a unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground. Pervious concrete is Instrumental in recharging groundwater, reducing storm water runoff, and meeting U.S environmental.

Protection Agency (EPA) storm water regulations. In fact, the use of pervious concrete is among the Best Management Practices (BMP) recommended by the EPA and by other agencies and geotechnical engineers across the country for the management of storm water runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swells, and other storm water management devices. In doing so, pervious concrete can lower overall project costs on first cost basis.

In previous concrete, carefully controlled amounts of water and cementitious materials are used to create a paste that forms a thick coating around aggregate particle. A pervious concrete mixture contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete, and flow rates for water through pervious concrete typically are around 480 in./hr (0.34 cm/s, which is 5 gal/ft2/ min or 200 L /m2/min), although they can be much higher. Both the low mortar content and high porosity also reduce strength compared to conventional concrete mixtures, but sufficient strength for many applications is readily achieved. While pervious concrete can be used for a surprising number of applications, its primary use is in pavement. This report will focus on the pavement applications of the material, which also has been referred to as porous concrete, permeable concrete, no-fines concrete, gap-graded concrete, and enhanced porosity concrete. Pervious concrete can be used for a number of applications, but its primary use is in road pavement such as in rural areas. This report will focus on the pavement applications of the concrete, which also has been referred to as porous concrete, permeable concrete, no-fines concrete, gap-graded concrete, and enhanced-porosity concrete. Pervious concrete is a zero-slump, open-graded material consisting of cement, coarse aggregate, admixtures and water. Pervious concrete contains little or no fine aggregates such as sand, it is sometimes referred to as "no-fines" concrete. Pervious concrete pavement in rural areas is a unique and effective means to achieve important environmental issues and support green, sustainable growth. By capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff.

B. Need Of Pervious Concrete In Rural Road Pavement

In rural areas larger amount of rainwater ends up falling on impervious surfaces such as parking lots, driveways, sidewalks, and streets rather than soaking into the soil.

This creates an imbalance in the natural ecosystem and leads to a host of problems including erosion, floods, ground water level depletion and pollution of rivers, as rainwater rushing across pavement surfaces picks up everything from oil and grease spills to de-icing salts and chemical fertilizers.

A simple solution to avoid these problems is to stop constructing impervious surfaces that block natural water infiltration into the soil. Rather than building them with conventional concrete, we should be switching to Pervious Concrete or Porous Pavement, a material that offers the inherent durability and low life-cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local watershed systems. Instead of preventing infiltration of water into the soil, pervious pavement assists the process by capturing rainwater in a network of voids and allowing it to percolate into the underlying soil.

C. Benefits Of Pervious Concrete

1) It reduces the storm water runoff.
2) Eliminates the need for detention ponds and other costly storm water management practices.
3) Mitigates surface runoff.
4) Replenishes the aquifers and water table.
5) Allows more efficient land development Prevents water from entering the stream and also prevents it from being pollution.

D. Advantages and Disadvantages

Pervious concrete is advantageous for several reasons. Of top concern is its increased permeability compared with conventional concrete. Pervious concrete shrinks less, has a lower unit weight, and higher thermal insulating values than conventional concrete. Although advantageous in many regards, pervious concrete has limitations that must be considered when planning its use. The bond strength between particles is lower than conventional concrete and therefore provides a lower compressive strength. There is potential for clogging thereby possibly reducing its permeability characteristics. Finally, 5 since the use of pervious concrete in the United States is recent, there is a lack of expert engineers and contractors required for its special installation.

E. Objectives

The main objective of this investigation is to develop a strong and durable pervious cement concrete (PCC) mix using different types of fine aggregates with varying the quantity of fine aggregates. In addition, it is also aimed to compare the properties of these PCC mixes. In the present investigation, two types of fine aggregates are used viz., Crushed Stone (CS) and River Sand (RS) are used. The percentage of fine aggregates used in PCC mix is 15 per cent. The properties of PCC mixes investigated are compressive strength, flexural strength, abrasion resistance, permeability, and clogging.

II. LITERATURE REVIEW

A. Pervious Concrete

Previous Studies to create a pervious concrete structure with optimum permeability and compressive strength, the amount of water, amount of cement, type and size of aggregate, and compaction must all be considered. A multitude of experiments have been previously conducted throughout the past few decades by a variety of researchers comparing some or all these elements. In 1976, V.M. Malhotra discussed pervious concrete as it relates to applications and properties. He provided details on such properties as consistency, proportions of materials, unit weight, compatibility, and curing to maximize permeability in the Pervious concrete.

Malhotra also conducted multiple experiments on various test cylinders to find a correlation between compressive strength and any of the material's properties. He concluded that the compressive strength of pervious concrete was dependent on the water cement ratio and the aggregate cement ratio. He also concluded that even the optimum ratios still would not provide compressive strengths comparable to conventional concrete. Malhotra went on to investigate the effects of compaction on compressive strengths. Malhotra also experimented on different types of aggregates and their effect on compressive strength.

B. Applications Of Pervious Concrete

1) Pervious Concrete as a Road pavement,
2) Low-volume pavements,
3) Sidewalks and pathways.,
4) Residential roads and driveways,

5) Parking lots,
6) Noise barriers,
7) Slope stabilization,
8) Hydraulic structures,
9) Swimming pool decks,
10) Tennis courts

Although not a new technology it was first used in 1852 (Ghafoori and Dutta 1995b), pervious concrete is receiving renewed interest, partly because of federal clean water legislation. The high flow rate of water through a pervious concrete pavement allows rainfall to be captured and to percolate into the ground, reducing storm water runoff, recharging groundwater, supporting sustainable construction, providing a solution for construction that is sensitive to environmental concerns, and helping owners comply with EPA storm water regulations. This unique ability of pervious concrete offers advantages to the environment, public agencies, and building owners by controlling rainwater on-site and addressing storm water runoff issues. This can be of particular interest in urban areas or where land is very expensive. Depending on local regulations and environment, a pervious concrete pavement and its sub base may provide enough water storage capacity to eliminate the need for retention ponds, swales, and other precipitation runoff containment strategies. This Pervious Concrete Pavements provides for more efficient land use and is one factor that has led to a renewed interest in pervious concrete. Other applications that take advantage of the high flow rate through pervious concrete include drainage media for hydraulic structures, parking lots, tennis courts, greenhouses, and pervious base layers under heavy duty pavements. Its high porosity also gives it other useful characteristics: it is thermally insulating and has good acoustical properties.

Fig. 1 Pervious base layers under heavy duty pavements

Although pavements are the dominant application for pervious concrete in the U.S., it also has been used as a structural material for many years in Europe (Malhotra 1976). Applications include walls for two-story houses, load-bearing walls for high-rise buildings (up to 10 stories), infill panels for high-rise buildings, sea groins, roads, and parking lots. All of these applications take advantage of the benefits of pervious concrete's characteristics. However, to achieve these results, mix design and construction details must be planned and executed with care.

Fig.2 pervious concrete pavements for parking lots

C. *Factors To Be Considered For Designing Pervious Concrete Pavement*

Pervious concrete used in road pavement systems must be designed to support the intended Traffic Load and contribute positively to the site-specific Storm Water Management Strategy. The designer selects the appropriate material properties, the appropriate pavement thickness, and other characteristics needed to meet the hydrological requirements (permeability, volume of voids, amount of rainfall expected, underlying soil properties) and anticipated traffic loads simultaneously.

III. MATERIALS

A. Materials Used In Pervious Concrete

1) Gravel
2) Cement
3) Water
4) Admixtures

Fig 3 Materials Used in Pervious Concrete

Pervious concrete uses the same materials as conventional concrete, with the exceptions that the fine aggregate typically is eliminated entirely, and the size distribution (grading) of the coarse aggregate is kept narrow, allowing for relatively little particle packing. This provides the useful hardened properties, but also results in a mix that requires different considerations in mixing, placing, compaction, and curing. The mixture proportions are somewhat less forgiving than conventional concrete mixtures—tight controls on batching of all the ingredients are necessary to provide the desired results. Often, local concrete producers will be able to best determine the mix proportions for locally available materials based on trial batching and experience. Table 3 provides typical ranges of materials.

B. Cementitious Materials

As in traditional concreting, portland cements (ASTM C 150, C 1157) and blended cements (ASTM C 595, C 1157) may be used in pervious concrete. In addition, supplementary cementitious materials (SCMs), such as fly ash and pozzolans (ASTM C 618) and ground-granulated blast furnace slag (ASTM C 989), may be used. Testing materials beforehand through trial batching is strongly recommended so that properties that can be important to performance (setting time, rate of strength development, porosity, and permeability, among others) can be determined.

C. Aggregate

Fine aggregate content is limited in pervious concrete and coarse aggregate is kept to a narrow gradation. Commonly used gradations of coarse aggregate include ASTM C 33 No. 67 (3⁄4 in. to No. 4), No. 8 (3⁄8 in. to No. 16), or No. 89 (3⁄8 in. to No. 50) sieves [in metric units: No. 67 (19.0 to 4.75 mm), No. 8 (9.5 to 2.36 mm), or No. 89 (9.5 to1.18 mm), respectively]. Single-sized aggregate up to 1 in. (25 mm) also has been used. ASTM D 448 also may be used for defining gradings. A narrow grading is the important characteristic. Larger aggregates provide a rougher surface. Recent uses for pervious concrete have focused on parking lots, low-traffic pavements, and pedestrian walkways. For these applications, the smallest sized aggregate feasible is used for aesthetic reasons. Coarse aggregate size 89 (3⁄8-in. or 9.5-mm top size) has been used extensively for parking lot and pedestrian application

D. Water

Water to cementitious materials ratios between 0.27 to 0.30 are used routinely with proper inclusion of chemical admixtures, and those as high as 0.34 and 0.40 have been used successfully. The relation between strength and water to cementitious materials ratio is not clear for pervious concrete because unlike conventional concrete, the total paste content is less than the voids content between the aggregates.

Therefore, making the paste strong may not always lead to increased overall strength. Water content should be tightly controlled. The correct water content has been described as giving the mixture a sheen, without flowing off the aggregate. A handful of pervious concrete formed into a ball will not crumble or lose its void structure as the paste flows into the spaces between the aggregates.

E. Admixtures

Chemical admixtures are used in pervious concrete to obtain special properties, as in conventional concrete. Because of the rapid setting time associated with pervious concrete, retarders or hydration-stabilizing admixtures are used commonly. Use of chemical admixtures should closely follow manufacturer's recommendations.

Air entraining admixtures can reduce freeze-thaw damage in pervious concrete and are used where freeze-thaw is a concern. ASTM C 494 governs chemical admixtures, and ASTM C 260 governs air-entraining admixtures. Proprietary admixture products that facilitate placement and protection of pervious pavements are also used.

F. Design

1) Two factors determine the design thickness of pervious pavements: the hydraulic properties, such as permeability and volume of voids, and the mechanical properties, such as strength and stiffness.
2) Pervious concrete used in pavement systems must be designed to support the intended traffic load and contribute positively to the site-specific storm water management strategy.
3) The designer selects the appropriate material properties, the appropriate pavement thickness, and other characteristics needed to meet the hydrological requirements and anticipated traffic loads simultaneously.
4) Separate analyses are required for both the hydraulic and the structural requirements, and the larger of the two values for pavement thickness will determine the final design thickness.

G. Hydrological Design Considerations

The design of a pervious concrete pavement must consider many factors. The three primary considerations are the amount of rainfall expected, pavement characteristics, and underlying soil properties.

However, the controlling hydrological factor in designing a pervious concrete system is the intensity of surface runoff that can be tolerated.

The amount of runoff is less than the total rainfall because a portion of the rain is captured in small depressions in the ground (depression storage), some infiltrates into the soil, and some is intercepted by the ground cover. Runoff also is a function of the soil properties, particularly the rate of infiltration: sandy, dry soils will take in water rapidly, while tight clays may absorb virtually no water during the time of interest for mitigating storm runoff.

Runoff also is affected by the nature of the storm itself; different sizes of storms will result in different amounts of runoff, so the selection of an appropriate design storm is important.

This section will briefly discuss these topics. In many situations, pervious concrete simply replaces an impervious surface. In other cases, the pervious concrete pavement system must be designed to handle much more rainfall than will fall on the pavement itself. These two applications may be termed "passive" and "active" runoff mitigation, respectively.

A passive mitigation system can capture much, if not all, of the "first flush," but is not intended to offset excess runoff from adjacent impervious surfaces. An active mitigation system is designed to maintain runoff at a site at specific levels. Pervious concrete used in an active mitigation system must treat runoff from other features on-site as well, including buildings, areas paved with conventional impervious concrete, and buffer zones, which may or may not be planted. When using an active mitigation system, curb, gutter, site drainage, and ground cover should ensure that flow of water into a pervious pavement system does not bring in sediment and soil that might result in clogging the system. One feasibility study found that by using pervious concrete for a parking lot roughly the size of a football field, approximately 9 acres (3.6 hectares) of an urbanized area would act hydrologically as if it were grass (Malcolm, 2002).

H. Rainfall

An appropriate rainfall event must be used to design pervious concrete elements. Two important considerations are the rainfall amount for a given duration and the distribution of that rainfall over the time period specified.

I. Pavement Hydrological Design

When designing pervious concrete storm water management Systems, two conditions must be considered. Permeability and storage capacity. Excess surface runoff—caused by either excessively low permeability or inadequate storage capacity—must be prevented.

J. Permeability

In general, the concrete permeability limitation is not a critical design criterion. Consider a passive pervious concrete pavement system overlying a well-draining soil. Designers should ensure that permeability is sufficient to accommodate all rain falling on the surface of the pervious concrete. For example, with a permeability of 3.5 gal/ft2/min (140 L/m2/min), a rainfall in excess of 340 in./hr (0.24 cm/s) would be required before permeability becomes a limiting factor. The permeability of pervious concretes is not a practical controlling factor in design. However, the flow rate through the sub grade may be more restrictive.

K. Storage Capacity

Storage capacity of a pervious concrete system typically is designed for specific rainfall events, which are dictated by local requirements. The total volume of rain is important, but the infiltration rate of the soil also must be considered. Details may be found in Lemming (in press). The total storage capacity of the pervious concrete system includes the capacity of the pervious concrete pavement, the capacity of any sub base used, and the amount of water which leaves the system by infiltration into the underlying soil. The theoretical storage capacity of the pervious concrete is its effective porosity: that portion of the pervious concrete which can be filled with rain in service. If the pervious concrete has 15% effective porosity, then every 1 in. (25 mm) of pavement depth can hold 0.15 in. (4 mm) of rain. For example, a 4-in. (100-mm) thick pavement with 15% effective porosity on top of impervious clay could hold up to 0.6 in. (15 mm) of rain before contributing to excess rainfall runoff. Another important source of storage is the sub base. Compacted clean stone used as a sub base has a design porosity of 40%; a conventional aggregate sub base, with higher fines content, will have a lower porosity (about 20%). From the example above, if 4 in. (100 mm) of pervious concrete with 15% porosity was placed on 6 in. (150 mm) of clean stone, the nominal storage capacity would be 3.0 in. (75 mm) of rain.

L. Structural Design Considerations

This section provides guidelines for the structural design of pervious concrete pavements. Procedures described provide a rational basis for analysis of known data and offer methods to determine the structural thickness of pervious concrete pavements. Pervious concrete is a unique material that has a matrix and behavior characteristics unlike conventional Portland cement concrete or other pavement materials. Although these characteristics differ from conventional concretes, they are predictable and measurable. Projects with good to excellent performance over service lives of 20 to 30 years provide a great deal of empirical evidence related to material properties, acceptable sub grades, and construction procedures. Laboratory research in these areas has only recently begun.

M. Pavement Structural Design

Pervious concrete pavements can be designed using either a standard pavement procedure (AASHTO, Win PAS, PCAPAV, ACI 325.9R, or ACI 330R) or using structural numbers derived from a flexible pavement design procedure. Regardless of the procedure used, guidelines for roadbed (sub grade) soil properties, pervious concrete materials characteristics, and traffic loads should be considered.

IV. CONSTRUCTIONS

A. Sub Grade And Sub Base Preparation

Uniformity of sub grade support is a key criterion for placing pervious pavement. As in other types of pavements, truck ruts and other irregularities must be smoothed and compacted prior to placement. Since sub grade and sub base preparation are critical components of pervious concrete pavement performance, refer to “Hydrological Design Considerations” and “Structural Design Considerations” elsewhere in this document for more information. Compaction to a minimum density of 90% to 95% of theoretical density per AASHTO T 180 often is recommended for consistent sub grade support; however, increasing the sub grade density decreases its permeability. Local geotechnical engineers may be the best source of knowledge regarding the properties of sub grade soils. Since pervious pavements contain minimal water and high porosity, care must be taken to ensure that the pavement does not dry out prematurely.

The sub grade must be moist (without free-standing water) prior to placement to prevent water from being removed from the lower portion of the pavement too soon. This is recommended practice for conventional concrete pavement placement if conditions for high evaporation rates are present, but is even more important in pervious concrete placement because the high voids can allow more rapid drying, with subsequent decrease in strength and durability, under less extreme conditions.

B. Batching and Mixing

The special properties of pervious concrete require tighter control of mixture proportioning. In particular, the water content of pervious concrete is limited to a narrow range to provide adequate strength and permeability, and prevent the paste from flowing off the aggregates and closing of the open structure. A limited paste content means that added water will have more drastic impact than that experienced in conventional concrete applications. Aggregate moisture level should be monitored carefully and accounted for, as both water absorbed by the aggregate and excess moisture supplied with the aggregate can be detrimental. Contractors and producers must work together to ensure a proper mixture prior to delivery at the job site. On some occasions, slight adjustments to the water content may be necessary at the job site to achieve proper consistency; however, this should be done with care because jobsite additions of water can be difficult to control.

The correct water content will provide a mix with sheen. A unit weight test is necessary to provide assurance of consistent mixture proportions. Unit weights between 100 lb/ft3 and 125 lb/ft3 (1600 kg/m3and 2000 kg/m3) are typical, and on-site measured values typically are required to be within 5% of the design unit weight. Aggregate and cement proportions will be established by testing and experience with locally available materials, as variations in materials characteristics (for example, cement setting times, strength development rates, aggregate shape, gradation, and density) will limit the usefulness of “cook book” or prescriptive mix designs. Almost certainly, the mixtures will be stiff. Conventional concrete mixing equipment is used, although mixing times may be extended compared to conventional concrete.

C. Transportation

Because pervious concrete has a low water content, special attention is required during transportation and placement. It’s very low slumps may make discharge from transit mixers slower than for conventional concrete; transit mixers with large discharge openings or paving mixers tend to provide a faster unloading time. A pervious pavement mixture should be discharged completely within one hour after initial mixing. The use of retarding chemical admixtures or hydration-stabilizing admixtures may extend discharge times to 11⁄2 hours or more. High ambient temperatures and windy conditions will have more pronounced effects relative to conventional pavements and should be taken into account.

D. Placement and Consolidation

A variety of placement techniques can be used for constructing pervious concrete pavements; as with conventional concrete, placement techniques are developed to fit the specific job site conditions. It should be noted that pervious concrete mixtures cannot be pumped, making site access an important planning consideration. Prior to placement, the sub base preparation and forms should be double-checked. Any irregularities, rutting, or misalignment should be corrected. Each load of concrete should be inspected visually for consistency and aggregate coating.

The stiff consistency of pervious concrete means that slump testing is not a useful method of quality control. Unit weight tests provide the best routine test for monitoring quality and are recommended for each load of pervious concrete. Placement should be continuous, and spreading and strike off should be rapid. Conventional formwork is used. Mechanical (vibrating) and manual screeds are used commonly, although manual screeds can cause tears in the surface if the mixture is too stiff. Other devices, such as laser screeds, could also be used.

For pavements, it is recommended to strike off about 1⁄2 to 3⁄4 in. (15 to 20 mm) above the forms to allow for compaction. One technique for accomplishing this (Paine 1992) is to attach a temporary wood strip above the top form to bring it to the desired height. After strike off, the strips are removed and the concrete is consolidated to the height of the form. Special height-adjusting vibrating screeds also have been used to provide the extra height.

With vibrating screeds, care should be taken that the frequency of vibration is reduced to avoid over-compaction or closing off the surface, resulting in blocked voids.

Edges near forms are compacted using a 1 ft by 1 ft (300 mm by 300 mm) steel tamp (like those used in decorative stamped concrete), a float, or other similar device to prevent raveling of the edges.

Fig 4 Pervious concrete is usually placed and then struck off

Consolidation generally is accomplished by rolling over the concrete with a steel roller (see Figures 12 and 13), compacting the concrete to the height of the forms. Because of rapid hardening and high evaporation rates, delays in consolidation can cause problems; generally, it is recommended that consolidation be completed within 15 minutes of placement.

Fig 5 Pervious concrete after screeding (left) and after compaction (right)

Fig 6 Compaction of pervious concrete with a steel roller.(R. Banka)

E. Finishing

Typically, pervious concrete pavements are not finished in the same way as conventional concrete pavements. Normal floating and towelling operations tend to close the top surface of the voids, which defeats the purpose (for most applications) of pervious concrete. For most pervious pavements, the “finishing” step is the compaction.

F. Joint Placement

Control joints should be place saw cutting joints also is possible, but is not preferred because slurry from sawing operations may block some of the voids, and excessive raveling of the joints often results. Removing covers to allow sawing also slows curing, and it is recommended that the surfaces be re-wet before the covering is replaced if prevention of random cracking of the pavement is desired, although the joint spacing is usually larger than for conventional concrete pavements because pervious concretes tend to shrink much less. Recommended joint spacing’s of 20 ft (6 m) (GCPA 1997) have been suggested, although some installations have had joint spacing’s of 45 ft (13.5 m) or more without uncontrolled cracking (Paine 1992). Prevention of uncontrolled reflective cracking is accomplished by installing joints at the same location as in the adjoining pavements. As for conventional pavements, joints one-fourth of the slab thickness provide good control of cracking, but can improve traction.

Because setting time and shrinkage are accelerated in pervious concrete construction, joint installation should be soon after consolidation, with a rolling joint tool. Another to saw cutting joints also is possible, but is not preferred.

As noted previously, some pervious concrete pavements are not jointed, as random cracking is not viewed as a significant deficit in the aesthetic of the pavement and has no significant affect on the structural integrity of the pavement.

Fig7 Joint rollers, commonly referred to as a “pizza cutter.”

G. Curing and Protection

The open structure and relatively rough surface of pervious concrete exposes more surface area of the cement paste to evaporation, making curing even more essential than in conventional concreting. Water is needed for the chemical reactions of the cement and it is critical for pervious concrete to be cured promptly. In some regions, it is common to apply an evaporation retarder before compaction to minimize any potential for surface water loss. Because pervious concrete pavements do not bleed, they can have a high propensity for plastic shrinkage cracking. In fact, “curing” for pervious slabs and pavements begins before the concrete is placed: the sub grade must be moistened to prevent it from absorbing moisture from the concrete.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

After placement, fog misting followed by plastic sheeting is the recommended curing procedure, and sheeting should remain in place for at least seven days. Using sand or dirt to hold plastic sheeting in place is not recommended because clogging of the voids could result from spillage on removal. Instead, securing plastic sheeting with lumber, rebar, stakes, or other methods is recommended. Curing should be started as soon as practical after placing, compacting, and jointing.

H. Opening to Traffic

For pavement applications that will see traffic in service, it is generally recommended that the pavements not be opened to construction or public traffic for seven days. Continuous curing is recommended until the pavement is opened.

Fig 8 Plastic sheeting should be used to cover the pervious concrete and be installed within a few minutes of consolidation to Prevent moisture loss

I. Engineering Properties

The plastic pervious concrete mixture is stiff compared to traditional concrete. Slumps, when measured, are generally less than 3⁄4 in. (20 mm), although slumps as high as 2 in (50 mm) have been used. When placed and compacted, the aggregates are tightly adhered to one another and exhibit the characteristic open matrix. For quality control or quality assurance, unit weight or bulk density is the preferred measurement because some fresh concrete properties, such as slump, are not meaningful for pervious concrete. Conventional cast cylinder strength tests also are of little value, because the field consolidation of pervious concrete is difficult to reproduce in cylindrical test specimens, and strengths are heavily dependent on the void content. Unit weights of pervious concrete mixtures are approximately 70% of traditional concrete mixtures. Concrete working time typically is reduced for pervious concrete mixtures. Usually, one hour between mixing and placing is all that is recommended. However, this can be controlled using retarders and hydration stabilizers that extend the working time by as much as 1.5 hours, depending on the dosage.

J. Hardened Properties

Density and Porosity: The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction, procedures used in placement. In-place densities on the order of 100 lb/ft3 to 125 lb/ft3 (1600 kg/m3 to 2000 kg/m3) are common, which is in the upper range of lightweight concretes. A pavement 5 in. (125 mm) thick with 20% voids will be able to store 1 in. (25 mm) of a sustained rainstorm in its voids, which covers the vast majority of rainfall events in the U.S. Wheon a 6-in. (150-mm) thick layer of open-graded gravel or crushed rock sub base, the storage capacity increases to as much as 3 in. (75 mm) of precipitation (see Figure 3 and discussion on Hydrological Design Considerations) placed.

Fig 9 Typical cross section of pervious concrete Pavement

K. Permeability

The flow rate through pervious concrete depends on the materials and placing operations. Typical flow rates for water through pervious concrete are 3gal/ft2/min (288 in./hr, 120 L /m2/min, or 0.2 cm/s) to 8 gal/ft2/min (770 in./hr, 320 L /m2/min, or 0.54 cm/s), with rates up to 17 gal/ft2/min (1650 in./hr, 700 L /m2/min, 1.2 cm/s) and higher having been measured in the laboratory (Crouch 2004).

L. Compressive Strength

Pervious concrete mixtures can develop compressive strengths in the range of 500 psi to 4000 psi (3.5MPa to 28MPa), which is suitable for a wide range of applications. Typical values are about 2500 psi (17MPa). As with any concrete, the properties, and combinations of specific materials, as well as placement techniques and environmental conditions, will dictate the actual in-place strength. Drilled cores are the best measure of in-place strengths, as compaction differences make cast cylinders less representative of field concrete.

M. Flexural Strength

Flexural strength in pervious concretes generally ranges between about 150 psi (1MPa) and 550 psi (3.8MPa). Many factors influence the flexural strength, particularly degree of compaction, porosity, and the aggregate cement (A/C) ratio. However, the typical application constructed with pervious concrete does not require the measurement of flexural strength for design.

N. Shrinkage

Drying shrinkage of pervious concrete develops sooner, but is much less than conventional concrete. Specific values will depend on the mixtures and materials used, but values on the order of 200 _ 10-6 have been reported (Malhotra 1976), roughly half that of conventional concrete mixtures. The material's low paste and mortar content is a possible explanation. Roughly 50% to 80% of shrinkage occurs in the first 10 days, compared to 20% to 30% in the same period for conventional concrete. Because of this lower shrinkage and the surface texture, many pervious concretes are made without control joints and allowed to crack randomly.

O. Durability

Pervious concrete pavement is a permeable pavement used to satisfy the need for both a pavement surface and stormwater management. Pervious concrete is created with narrowly graded coarse aggregate that is coated in a thin layer of cement paste or mortar. This allows for an interconnected pore structure through which water percolates. In addition to designing for hydrology (see Hydrologic Design of Pervious Concrete), pervious concrete is structurally designed using normal design methods for pavements. The final key aspect to designing a pervious concrete pavement takes the durability into consideration. Concrete durability is the ability to resist weathering action, chemical attack, and abrasion while maintaining desired engineering properties for the expected service life of the structure. Pervious concrete can become clogged, which directly affects the hydrologic performance and may indirectly affect other aspects of durability, such as freeze-thaw resistance, dicer salt scaling resistance, and sulphate resistance. Abrasion resistance of pervious concrete is also of concern, particularly in locations that use snow ploughs or have turning traffic. Carbonation and corrosion resistance are not concerns with pervious concrete as it is neither recommended nor necessary to use reinforcing steel bars or welded wire reinforcement.

P. Freeze-Thaw Resistance

Freeze-thaw resistance of pervious concrete in the field appears to depend on the saturation level of the voids in the concrete at the time of freezing. In the field, it appears that the rapid draining characteristics of pervious concrete prevent saturation from occurring. Anecdotal evidence also suggests that snow covered pervious concrete clears quicker, possibly because its voids allow the snow to thaw more quickly than it would on conventional pavements. In fact, several pervious concrete placements in North Carolina and Tennessee have been in service for more than 10 years.

Note that the porosity of pervious concrete from the large voids is distinctly different from the microscopic air voids that provide protection to the paste in conventional concrete in a freeze-thaw environment. When the large open voids are saturated, complete freezing can cause severe damage in only a few cycles.

Standardized testing by ASTM C 666 may not represent field conditions fairly, as the large open voids are kept saturated in the test, and because the rate of freezing and thawing is rapid.

Neithalath (2003) found that even after 80 cycles of slow freezing and thawing (one cycle/day), pervious concrete mixtures maintained more than 95% of their relative dynamic modulus, while the same mixtures showed less than 50% when tested at a more rapid rate (five to six cycles/day). It was noted that better performance also could be expected in the field because of the rapid draining characteristics of pervious concrete. Research indicates that entrained air in the paste dramatically improves freeze-thaw protection for pervious concrete (Neithalath 2003; Malhotra 1976). In addition to the use of air-entraining agents in the cement paste, placing the pervious concrete on a minimum of 6 in. (150 mm) (often up to 12 in. (300 mm) or even 18 in. (450 mm)) of a drainable rock base, such as 1-in. (25-mm) crushed stone, is normally recommended in freeze-thaw environments where any substantial moisture will be encountered during freezing conditions (NRMCA 2004a).

Q. Sulphate Resistance

Aggressive chemicals in soils or water, such as acids and sulphates, are a concern to conventional concrete and pervious concrete alike, and the mechanisms for attack are similar. However, the open structure of pervious concrete may make it more susceptible to attack over a larger area. Pervious concretes can be used in areas of high-sulphate soils and ground waters if isolated from them. Placing the pervious concrete over a 6-in. (150-mm) layer of 1-in. (25-mm) maximum top size aggregate provides a pavement base, storm water storage, and isolation for the pervious concrete. Unless these precautions are taken, in aggressive environments, recommendations of ACI 201 on water cement ratio, and material types and proportions should be followed strictly.

R. Abrasion Resistance

Because of the rougher surface texture and open structure of pervious concrete, abrasion and ravelling of aggregate particles can be a problem, particularly where snowploughs are used to clear pavements. This is one reason why applications such as highways generally are not suitable for pervious concretes. However, anecdotal evidence indicates that pervious concrete pavements allow snow to melt faster, requiring less ploughing. Most pervious concrete pavements will have a few loose aggregates on the surface in the early weeks after opening to traffic. These rocks were loosely bound to the surface initially, and popped out because of traffic loading. After the first few weeks, the rate of surface ravelling is reduced considerably and the pavement surface becomes much more stable. Proper compaction and curing techniques will reduce the occurrence of surface ravelling.

S. Performance

After placement, pervious concrete has a textured surface which many find aesthetically pleasing and which has been compared to a Rice Krispies treat. Its low mortar content and little (or no) fine aggregate content yield a mixture with a very low slump, with a stiffer consistency than most conventional concrete mixtures. Despite the high voids content, properly placed pervious concrete pavements can achieve strengths in excess of 3000 psi (20.5MPa) and flexural strengths of more than 500 psi (3.5MPa). This strength is more than adequate for most low-volume pavement applications, including high axle loads for garbage truck and emergency vehicles such as fire trucks. More demanding applications require special mix designs, structural designs, and placement techniques. Pervious concrete is not difficult to place, but it is different from conventional concrete, and appropriate construction techniques are necessary to ensure its performance. It has a relatively stiff consistency, which dictates its handling and placement requirements. The use of a vibrating screed is important for optimum density and strength. After screeding, the material usually is compacted with a steel pipe roller.

There are no bull floats, darbies, trowels, etc. used in finishing pervious concrete, as those tools tend to seal the surface. Joints, if used, may be formed soon after consolidation, or installed using conventional sawing equipment. (However, sawing can induce raveling at the joints.) Some pervious concrete pavements are placed without joints. Curing with plastic sheeting must start immediately after placement and should continue for at least seven days. Careful engineering is required to ensure structural adequacy, hydraulic performance, and minimum clogging potential.

T. Environmental Benefits

As mentioned earlier, pervious concrete pavement systems provide a valuable stormwater management tool under the requirements of the EPA Storm Water Phase II Final Rule (EPA 2000). Phase II regulations provide programs and practices to help control the amount of contaminants in our waterways. Impervious pavements—particularly parking lots—collect oil, anti-freeze, and other automobile fluids that can be washed into streams, lakes, and oceans when it rains. EPA Storm Water regulations set limits on the levels of pollution in our streams and lakes.

To meet these regulations, local officials have considered two basic approaches: 1) reduce the overall runoff from an area, and 2) reduce the level of pollution contained in runoff. Efforts to reduce runoff include zoning ordinances and regulations that reduce the amount of impervious surfaces in new developments (including parking and roof areas), increased green space requirements, and implementation of “storm water utility districts” that levy an impact fee on a property owner based on the amount of impervious area. Efforts to reduce the level of pollution from storm water include requirements for developers to provide systems that collect the “first flush” of rainfall, usually about 1 in. (25 mm), and “treat” the pollution prior to release. Pervious concrete pavement reduces or eliminates runoff and permits “treatment” of pollution: two studies conducted on the long-term pollutant removal in porous pavements suggest high pollutant removal rates. By capturing the first flush of rainfall and allowing it to percolate into the ground, soil chemistry and biology are allowed to “treat” the polluted water naturally. Thus, storm water retention areas may be reduced or eliminated, allowing increased land use. Furthermore, by collecting rainfall and allowing it to infiltrate, groundwater and aquifer recharge is increased, peak water flow through drainage channels is reduced and flooding is minimized. In fact, the EPA named pervious pavements as a BMP for storm water pollution prevention (EPA 1999) because they allow fluids to percolate into the soil. Another important factor leading to renewed interest in pervious concrete is an increasing emphasis on sustainable construction. Because of its benefits in controlling storm water runoff and pollution prevention, pervious concrete has the potential to help earn a credit point in the U.S. Green Building Council’s Leadership in Energy & Environmental Design (LEED) Green Building Rating System (PCA 2003 and USGBC 2003), increasing the chance to obtain LEED project certification. This credit is in addition to other LEED credits that may be earned through the use of concrete for its other environmental benefits, such as reducing heat island effects (Sustainable Site Credit 7.1), recycled content, and regional materials . The light color of concrete pavements absorbs less heat from solar radiation than darker pavements, and the relatively open pore structure of pervious concrete stores less heat, helping to lower heat island effects in urban areas. Trees planted in parking lots and city sidewalks offer shade and produce a cooling effect in the area, further reducing heat island effects. Pervious concrete pavement is ideal for protecting trees in a paved environment. (Many plants have difficulty growing in areas covered by impervious pavements, sidewalks and landscaping, because air and water have difficulty getting to the roots.) Pervious concrete pavements or sidewalks allow adjacent trees to receive more air and water and still permit full use of the pavement. Pervious concrete provides a solution for landscapers and architects who wish to use greenery in parking lots and paved urban areas. Although high-traffic pavements are not a typical use for pervious concrete, concrete surfaces also can improve safety during rainstorms by eliminating Ponding (and glare at night), spraying, and risk of hydroplaning.

V. CONCLUSIONS

1) The following conclusion comes through the study of the pervious concrete pavement in rural areas becomes more suitable to meet the rural area requirement such as to reduce the storm water runoff, to increase the ground water level, to eliminate the costly storm water management practices.
2) Pervious concrete is the relatively new concrete for the pavement construction in rural areas having cost benefits.
3) Pervious concrete extensively used worldwide because of their environmental benefits, hydraulic and durability properties.

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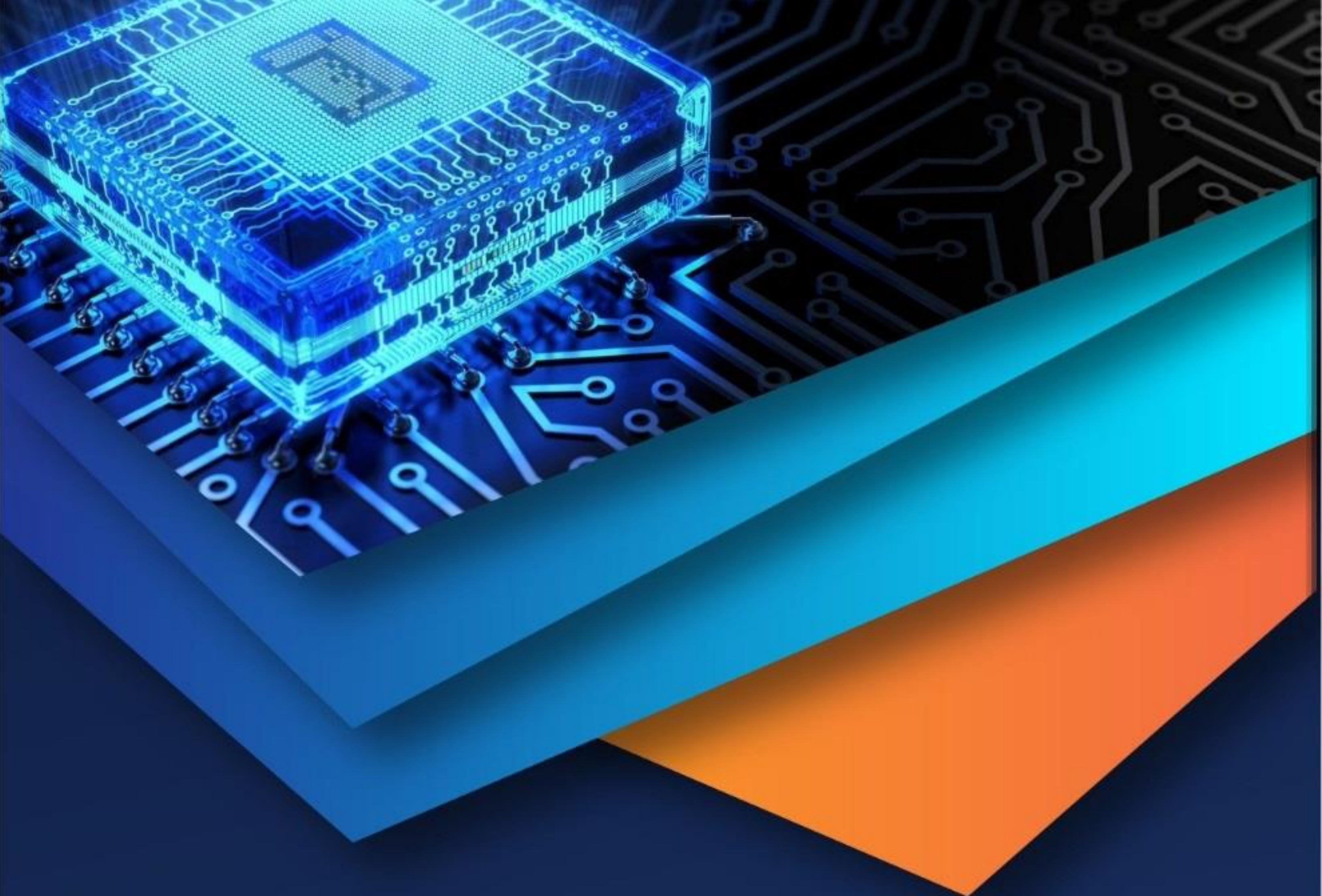

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