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"ANALESIS OF PROPERTIES OF PERVIOUS CONCRETE"

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Abstract - *Pervious concrete is a special type of concrete, which consists of cement, coarse aggregates, water and if required, admixtures and other cementitious materials. As there are no fine aggregates used in the concrete matrix, the void content is more which allows the water to flow through its body. So the pervious concrete is also called as Permeable concrete and Porous concrete.*

There is lot of research work is going in the field of pervious concrete. The compressive strength of pervious concrete is less when compared to the conventional concrete due to its porosity and voids. Hence, the usage of pervious concrete is limited even though it has lot of advantages. If the compressive strength and flexural strength of pervious concrete is increased, then it can be used for more number of applications. For now, the usage of pervious concrete is mostly limited to light traffic roads only. If the properties are improved, then it can also be used for medium and heavy traffic rigid pavements also. Along with that, the pervious concrete eliminates surface runoff of storm water, facilitates the ground water recharge and makes the effective usage of available land

The main aim of our project is to improve the strength characteristics of pervious concrete. But it can be noted that with increase in strength, the permeability of pervious concrete will be reduced. Hence, the improvement of strength should not affect the permeability property because it is the property which serves its purpose.

1.INTRODUCTION

Pervious concrete which is also known as the no-fines, porous, gap-graded, and permeable concrete and Enhance porosity concrete have been found to be a reliable storm water management tool. By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate). When pervious concrete is used for paving, the open cell structures allow storm water to filter through the pavement and into the underlying soils. In other words, pervious concrete helps in protecting the surface of the pavement and its environment.

As stated above, pervious concrete has the same basic constituents as conventional concrete, 15 -30% of its volume consists of interconnected void network, which allows water to pass through the concrete. Pervious concrete can allow the passage of 11.35-18.97 liters of water per minute through its open cells for each square foot (0.0929m2) of surface area which is far greater than most rain occurrences. Apart from being used to eliminate or reduce the need for expensive retention ponds, developers and other private companies are also using it to free up valuable real estate for development, while still providing a paved park.

Pervious concrete is also a unique and effective means to address important environmental issues and sustainable growth. When it rains, pervious concrete automatically acts as a drainage system, thereby putting water back where it belongs. Pervious concrete is rough textured, and has a honeycombed surface, with moderate amount of surface ravelling which occurs on heavily travelled roadways. Carefully controlled amount of water and cementitious materials are used to create a paste. The paste then forms a thick coating around aggregate particles, to prevent the flowing off of the paste during mixing and placing. Using enough paste to coat the particles maintain a system of interconnected voids which allow water and air to pass through. The lack of sand in pervious concrete results in a very harsh mix that negatively affects mixing, delivery and placement. Also, due to the high void content, pervious concrete is light in weight (about 1600 to 2000 kg/m3). Pervious concrete. void structure provides pollutant captures which also add significant structural strength as well. It also results in a very high permeable concrete that drains quickly.

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Figure1.1: pervious concrete cube blocks

Pervious concrete system has advantages over impervious concrete in that it is effective in managing run-off from paved surfaces, prevent contamination in run-off water, and recharge aquifer, repelling salt water intrusion, control pollution in water seepage to ground water recharge thus, preventing subterranean storm water sewer drains, absorbs less heat than regular concrete and asphalt, reduces the need for air conditioning. Pervious concrete allows for increased site optimization because in most cases, its use should totally limit the need for detention and retention ponds, swales and other more traditional storm water management devices that are otherwise required for compliances with the Federal storm water regulations on commercial sites of one acre or more. By using pervious concrete, the ambient air temperature will be reduced, requiring less power to cool the building. In addition, costly storm water structures such as piping, inlets and ponds will be eliminated. Construction scheduling will also be improved as the stone recharge bed will be installed at the beginning of construction, enhancing erosion control measures and preventing rain delays due to harsh site conditions. Apparently, when compared to conventional concrete, pervious concrete has a lower compressive strength, greater permeability, and a lower unit weight (approximately 70% of conventional concrete). However, pervious concrete has a greater advantage in many regards. Nevertheless, it has its own limitations which must be put in effective consideration when planning its use. Structurally when higher permeability and low strength are required, the effect of variation in aggregate size on strength and permeability for the same aggregate cement ratio need to be investigated.

Figur1.3: water flowing through pervious concrete cube

1.1 General Properties of Pervious Concrete:

The plastic pervious concrete mixture is stiff compared to traditional concrete. Slumps, when measured, are generally less than 20mm, although slumps as high as 50mm have been used. However, slump of pervious concrete has no correlation with its workability and hence should not be specified as an acceptance criterion. Typical densities and void contents are on the order of 1600 kg/m3 to 2000 kg/m3 and 20 to 25% respectively. The infiltration rate (permeability) of pervious concrete will vary with aggregate size and density of the mixture, but will fall into the range of 80 to 720 litres per minute per square meter. A moderate porosity pervious concrete pavement system will typically have a permeability of 143 litres per minute per square meter. Perhaps nowhere in the world would one see such a heavy rainfall. In contrast the steady state infiltration rate of soil ranges from 25 mm/hr to 0.25 mm/hr. This clearly suggests that unless the pervious concrete is severely clogged up due to possibly poor maintenance it is unlikely that the permeability of pervious concrete is the controlling factor in estimating runoff (if any) from a pervious concrete pavement. For a given rainfall intensity the amount of runoff from a pervious concrete pavement system is controlled by the soil infiltration rate and the amount of water storage available in the pervious concrete and aggregate base (if any) under the pervious concrete.

Generally for a given mixture proportion strength and permeability of pervious concrete are a function of the concrete density. Greater the amount of consolidation higher the strength, and lower the permeability. Since it is not possible to duplicate the in-place consolidation levels in a pervious concrete pavement one has to be cautious in interpreting the properties of pervious concrete specimens prepared in the laboratory. Such specimens may be adequate for quality assurance namely to ensure that the supplied concrete meets specifications. Core testing is recommended for knowing the in-place properties of the pervious concrete pavement. The relationship between the w/cm and compressive strength of conventional concrete is not significant. A high w/cm can result in the paste flowing from the aggregate and filling the void structure. A low w/cm can result in reduced adhesion between aggregate particles and placement problems. Flexural strength in pervious concretes generally ranges between about 1 MPa and 3.8 MPa. Numerous successful projects have been successfully executed and have lasted several winters in harsh Northern climates. This is possibly because pervious concrete is unlikely to remain saturated in the field.

The freeze thaw resistance of pervious concrete can be enhanced by the following measures

1. Use of fine aggregates to increase strength and slightly reduce voids content to about 20%.
2. Use of air-entrainment of the paste.
3. Use of a perforated PVC pipe in the aggregate base to capture all the water and let it drain away below the pavement. Abrasion and ravelling could be a problem. Good curing practices and appropriate w/cm (not too low) is important to reduce ravelling. Where as severe ravelling is unacceptable some loose stones on a finished pavement is always expected. Use of snow ploughs could increase ravelling. A plastic or rubber shield at the base of the plough blade may help to prevent damage to the pavement

1.2 Benefits of Pervious Concrete:

Pervious concrete pavement systems provide a valuable stormwater management tool under the requirements of the EPA Storm Water Phase II Final Rule Phase II regulations provide programs and practices to help control the amount of contaminants in our waterways. Impervious pavement 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.

They are

1) Reduce the overall runoff from an area
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 "stormwater 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 stormwater include requirements for developers to provide systems that collect the "first flush" of rainfall, usually about 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, stormwater retention areas may be reduced or eliminated, allowing increasedland 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 stormwater 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 stormwater 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, 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 recycled content and regional materials. The light colour 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.

2.Major applications of pervious concrete

- Low-volume pavements
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Low water crossings
- Tennis courts
- Sub base for conventional concrete pavements
- Slope stabilization
- Well linings
- Hydraulic structures
- Swimming pool decks
- Pavement edge drains and Tree grates in sidewalks
- Groins and seawalls
- Noise barriers
  Walls (including load-bearing)

3. EXPERIMENTAL WORK

MATERIALS USED

3.1.1 CEMENT

Cement is a key to infrastructure industry and is used for various purposes and also made in many compositions for a wide variety of uses. Cements may be named after the principal constituents, after the intended purpose, after the object to which they are applied or after their characteristic property. Cement used in construction are sometimes named after their commonly reported place of origin, such as Roman cement, or for their resemblance to other materials, such as Portland cement, which produces a concrete resembling the Portland stone used for building in Britain. The term cement is derived from the Latin word Caementum, which is meant stone chippings such as used in Roman mortar not-the binding material itself. Cement, in the general sense of the word, described as a material with adhesive and cohesive properties, which make it capable of bonding mineral fragments in to a compact whole. The first step of reintroduction of cement after decline of the Roman Empire was in about 1790, when an Englishman, J.Smeaton, found that when lime containing a certain amount of clay was burnt, it would set under water. This cement resembled that which had been made by the Romans. Further investigations by J. Parker in the same decade led to the commercial production of natural hydraulic cement.

Table 3.1: Typical composition of ordinary Portland cement

Name of compound	Chemical Composition	Abbreviation
Tricalcium Silicate	$3CaO.SiO_2$	C_3S
Dicalcium Silicate	$2CaO.SiO_2$	C_2S
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A
Tetracalcium alumino ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

3.1.2 AGGREGATES:

3.1.2.1 Coarse aggregates:

Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However, it is now known that the type of aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete. They can form 80% of the concrete mix so their properties are crucial to the properties of concrete. Aggregates can be broadly classified into four different categories: these are heavyweight, normal weight, lightweight and ultra-lightweight aggregates. However in most concrete practices only normal weight and lightweight aggregates are used. The other types of aggregates are for specialist uses, such as nuclear radiation shielding provided by heavyweight concrete and thermal insulation using lightweight concrete.

3.1.2.2 FINE AGGREGATES:

While pervious concrete is considered a "no-fines" concrete, a small percentage of fine particles can be added to increase the compressive strength of the pervious concrete mix. The inclusion of fine particles has a direct correlation to the paste/mortar strength. Providing a thicker paste layer around the coarse aggregates results in improved compressive strength (Schaefer et al 2009). There is a significant relationship between compressive strength and sand to gravel ratio. When the sand to gravel ratio is increased to 8 %, the mortar bulks up and increases the strength. When the sand to gravel ratio increases beyond the 8 % mark, the 7 day compressive strength begins to fall (Schaefer et al 2009). Both Europe and Japan have been using smaller aggregates as well as the inclusion of sand for their mix design. An optimization of 10%-20% of fine sand to coarse aggregate has been shown to increase compressive strength from 14 to 19 MPa. A slight decrease in permeability correlates to the increase in fine particles.

3.1.3 WATER:

While any potable water can be used for mixing, the amount of water is critical for the formation of the voids in pervious concrete. Water-to-cement ratios can range from 0.27 to 0.30 with ratios as high as 0.40. Careful control of water is critical. A mix design with little water can create a very weak binder. This will create a very dry mix that is susceptible to spalling and crumbling.

3.1.4 SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS):

SCM includes fly ash, pozzolans, and slag can be added to the cement. These influence concrete performance, setting time, rate of strength development, porosity, permeability, etc., The key to high-performance concrete is the use of SCMs. Silica fume, fly ash, and blast furnace slag all increase durability by decreasing permeability and cracking

Silica fume is a by-product of silicone production. It consists of superfine spherical particles which significantly increase the strength and durability of concrete. Used frequently for high-rise buildings, it produces concrete that exceeds 140 MPa compressive strength. Silica fume can replace cement in quantities of 5-12%. Fly ash is the waste by-product of burning coal in electrical power plants; it used to be land filled, but now a significant amount is used in cement. This material can be used to replace 5-65% of the Portland cement Blast furnace slag is the waste by-product of steel manufacturing. It imparts added strength and durability to concrete, and can replace 20-70% of the cement in the mix.

In our project work, we have used fly ash and rice husk ash and mixture of both fly ash and rice husk ash as the partial replacement of cement in the quantities of 10% of cement.

3.1.4.1 Fly ash:

Fly ash, also known as "pulverised fuel ash", is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

3.1.4.2 Rice Husk Ash:

Rice husk can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon.RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature. Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash. Although the studies on pozzolanic activity of RHA, its use as a supplementary cementitious material, and its environmental and economical benefits are available in many literatures, very few of them deal with rice husk combustion and grinding methods. The optimized RHA, by controlled burn and/or grinding, has been used as a pozzolanic material in cement and concrete. Using it provides several advantages, such as improved strength and durability properties, and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions. For this reason, this study investigates the strength activity index of mortars containing residual RHA that is generated when burning rice husk pellets and RHA as received after grinding residual RHA. The effect of partial replacement of cement with different percentages of ground RHA on the compressive strength and durability of concrete is examined.

3.2.5 Mix Design Criteria:

Pervious concrete uses the same materials as conventional concrete, except that there is usually little or no fine aggregate. The quantity, proportions, and mixing techniques affect many properties of pervious concrete, in particular the void structure and strength. Usually single sized coarse aggregate up to 20 mm size normally adopted. Larger size aggregates provide a rougher concrete finish while smaller size aggregates provide smoother surface that may be better suited for some application such as pedestrian pathways. Although the coarse aggregate size 6 mm to 20 mm are used, the most common being 10 mm fairly uniform size is used. The aggregates may be rounded like gravel or angular like crushed stone

The binder normally used in ordinary Portland cement (OPC). Pozzolanic materials like fly ash, blast furnace slag and silica fume can also be used. However, use of pozzolanic materials will affect setting time, strength, porosity and permeability of the resulting concrete. Addition of fine aggregate will reduce the porosity and increase the strength of concrete. Chemical admixtures like water reducing admixture, retarders, hydration stabilizing admixtures, viscosity modifying admixtures and internal curing admixtures are used. Pervious concrete uses same materials as conventional concrete, except that there are usually No or little fine aggregates. The size of the coarse aggregate used is kept fairly uniform in size to minimize surface roughness and for a better aesthetic, however sizes can vary from 6.25 mm to 12.5 mm. Water to cement ratio should be within 0.27 to 0.34. Ordinary Portland cement and blended cements can be used in pervious concrete. Water reducing admixtures and retarders can be used in pervious concrete.

3.2.6 NRMCA procedure for Pervious Concrete Mixture Proportioning:

The following mixture proportioning approach can be used to quickly arrive at pervious concrete mixture proportions that would help attain void content of freshly mixed pervious concrete when measured in accordance with ASTM C1688 similar to the target value.

(1) Determine the dry-rodded unit weight of the aggregate and calculate the void content.

(2)

Estimate the approximate percentage and volume of paste needed. The paste volume (PV) is then estimated as follows: Vp (%) = Aggregate Void Content (%) + CI (%) - Vvoid (%) Where, CI = compaction index and

Vvoid = design void content of the pervious concrete mix. The value of CI can be varied based on the anticipated consolidation to be used in the field. For greater consolidation effort a compaction index value of 1 to 2% may be more reasonable.

For lighter level of consolidation a value of 7 to 8% can be used. NRMCA used a value of 5% to get similar values between measured fresh pervious concrete void content (ASTM C1688) and design void content. Using a smaller value for CI (%) will reduce the paste volume.

(2) Calculate the paste volume, Vp in ft3 per cubic yard of pervious concrete:

Vp, ft3 = Vp (%) × 27

(3) Select the w/c ratio for the paste. Recommended values are in the range of 0.25 to 0.36.

(4) Calculate the absolute volume of cement vc,ft3 = vp/[1+(w/c*RDc)]
Where: RDc is the specific gravity of cement (typically 3.15)

(5) Calculate the volume of water, Vw

Vw, ft3 = Vp – Vc (6) Calculate the volume of SSD aggregate (Vagg)

Vagg = 27 – (Vp +Vvoid) Where: Vvoid is the design void content for the pervious concrete mix.

Convert the volumes to weights of ingredients per cubic yard and for trial batches: Cement (lb/yd3)

= Vc × RDc × 62.4 Water (lb/yd3)

= Vw × 62.4 SSD Coarse Aggregate (lb/yd3)

= Vagg × RDagg × 62.4

Trial batches are prepared to evaluate mix characteristics of the pervious concrete mixture. Make appropriate adjustments are made to account for aggregate moisture content. If paste is high, pick a lower value or change CI (%). Avoid excessive cementitious content should be avoided. The consistency of the paste can be evaluated separately to ensure that it is not too dry or causes paste run down by being too wet. The density of the mixture should be measured in accordance with ASTM C1688 from which the void content is calculated to ensure that values are in line with the design void content. Then evaluate mixture for consistency, specification requirements and placement method used by the pervious concrete

3.3 COMPRESSIVE STRENGTH AND PERMEABILITY OF PERVIOUS CONCRETE

3.3.1 Compressive Strength of Normal Concrete

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, Quality control during production of concrete etc., Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. For cube test two types of specimens either cubes of 150 mm X 150 mm X 15 mm or 100 mm X 100 mm x 100 mm depending upon the size of aggregate are used. For most of the works cubical moulds of size 150 mm x 150 mm x 150 mm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

Table3.5: Compressive strength of concrete at various ages

Age	Strength
1 Day	16%
3 Day	40%
7 Day	65%
14 Day	90%
28 Day	99%

3. CONCLUSIONS

- The size of coarse aggregates, water to cement ratio and aggregate to cement ratio plays a crucial role in strength of pervious concrete.
- The void ratio and unit weight are two important parameters of pervious concrete in the context of mix design.
- The compressive strength and co-efficient of permeability of pervious concrete are inversely proportional to each other up to addition of 8% of fines.
- Among the two methods of increasing compressive strength of pervious concrete, the addition of fines has gave more value when compared to replacement of cementitious materials.
- The addition of fines and replacement of Cementitious will reduce the permeability capacity of pervious concrete. The compressive strength of pervious concrete is increased by 4.36% when 5% fine aggregates were added to the standard pervious concrete.
- The compressive strength of pervious concrete is increased by 6.69% when 6% fine aggregates were added to the standard pervious concrete.
- The compressive strength of pervious concrete is increased by 12.96% when 7% fine aggregates were added to the standard pervious concrete.
- The compressive strength of pervious concrete is increased by a maximum of 14.57% when 8% fines were added to standard pervious concrete.
- The compressive strength of pervious concrete is increased by 11.44% when 9% fine aggregates were added to the standard pervious concrete. The compressive strength of pervious concrete is

increased by 8.59% when 10% fine aggregates were added to the standard pervious concrete.

- The compressive strength of pervious concrete is increased by 8.59% when 10% fly ash was replaced in the place of cement.
- The compressive strength of pervious concrete is increased by 13.62% when 10% Rice Husk Ash was replaced in the place of cement.

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