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Pervious Concrete

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***Abstract:*— Pervious concrete is one of the most effective pavement materials to address a number of important environmental issues, such as recharging groundwater and reducing storm water runoff. The amount of general purpose Portland cement has been reduced by introducing fly ash as a cementations agent in pervious concrete samples. The properties of various pervious concrete samples including density, porosity, compressive strength, water permeability and drying shrinkage have been measured. There are two types of porous pavement: porous asphalt and pervious concrete. porous asphalt pavements consisits of an open graded coarse aggregate, bonded together by asphalt cement ,with sufficient inter connected to make it highly to water. Pervious concrete consists of specially formulated mixtures of Portland and cement, uniform, open graded coarse aggregate and water. Pervious concrete has enough void space to allow rapid percolation of liquids thorough the pavement .pervious concrete is traditionally used in parking areas, areas with high traffic, walk ways in the parks and gardens, residential streets, pedestrians walkway and green houses, basket ball courts and volley ball courts etc. Pervious concrete is an important application for the sustainable construction and is one of many low impact development techniques used builders to protect water quality.**

***Keywords:* pervious concrete; porous concrete; cement; course aggregate; water.**

I. INTRODUCTION

Pervious concrete which is also known as the no fines, porous, gap graded and permeable concrete and enhance porosity concrete as been found to be reliable storm water management tool. By definition pervious concrete is mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate) with or without admixtures 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 that is, 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 3-5 gallons (0.014 to0.023 m.cu) of water per minute through its open cells for each sq.ft (0.0929 m. sq) of surface area which is far greater than most rain occurrences. A part 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 one of the most effective pavement materials to address a number of important environmental issues, and sustainable growth. When it rains, perviuos concrete automatically acts as a drainage system, thereby putting water back where it belongs. Pervious concrete is rough textured, and has a honey combed surface, with moderate amount of surface raveling which occurs on heavily travelled roadways (concrete network, 2009) . Carefully controlled amount of water and cementitious materials are used to create a paste (dan, 2003) 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 harsh mix that negatively affects mixing, delivery and placement. Also, due to the high void content, pervious concrete is light in weight (abiut 1600 to 1900 kg per m.cu) .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.

Sustainable construction designs have become extremely popular within the last few years. Reducing the strain on our environment is essential to the overall health and wellbeing of our society. While a variety of new designs and technologies have transpired from this green movement, one of the more profound impacts has been in the area of storm water management (SWM). Named one of the best management practices for SWM quality, pervious concrete has the ability to capture the runoff of rainwater and remove trace pollutants (NRMCA 2004). While pervious concrete has been around for many years,

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it has seen a significant increase in interest in recent years with the adoption of the federal clean water legislation. One of its first uses was in southern Georgia where the preservation of the natural ecosystem played an important role in selecting pervious concrete (Ferguson 2005). Since then, other states such as Florida, New Mexico, Utah, California, Oklahoma, Illinois, and Wisconsin have implemented pervious concrete designs (Mathis 1990). Water Sensitive Urban Design (WSUD) is a practice that is emerging throughout the world ASA cutting edge initiative adopted to deliver improved receiving water health and where possible, contribute to producing fit-for-purpose water for use in urban communities. WSUD is a structural initiative that is used for a given set of conditions to reduce the quantity and improve the quality of storm water runoff in the most cost-effective manner. Pervious pavements have been identified in Australia as a successful element of the WSUD concept.

Pervious concrete can be used in a wide range of applications, although its primary use is in pavements which are in: residential roads, alleys and driveways, low volume pavements, low water crossings, sidewalks and pathways, parking areas, tennis courts, slope stabilization, sub-base for conventional concrete pavements etc. 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 sub terrain 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.

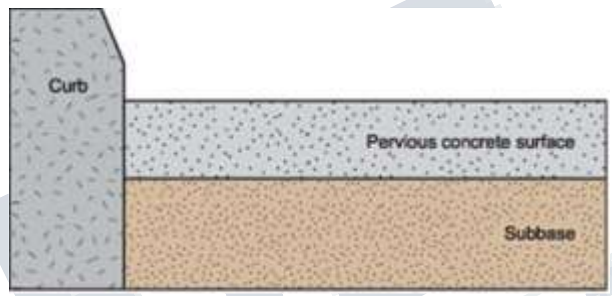
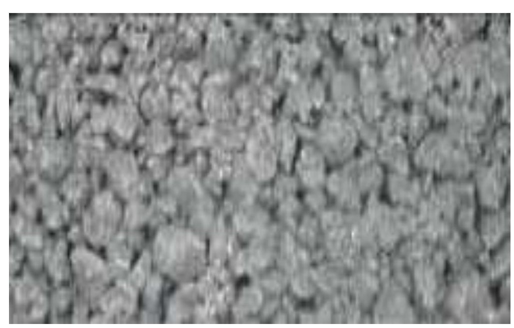


Figure 1.1: Section of a Typical Pervious Concrete Pavement

1.1 Types of Pervious Pavements

There are several types of pervious pavements that are used in practice. The three common types as shown in Figure 2.2 are pervious concrete, pervious interlocking concrete pavers, and concrete grid pavers (Collins et al 2008 and Bean et al 2007).



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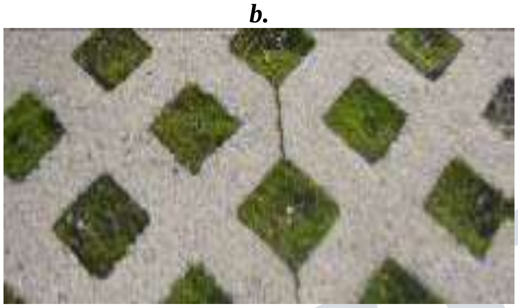
b.



c.

Figure 1.2: Types of Pervious Pavements a. Pervious Concrete, b. Pervious Interlocking Concrete Pavers, c. Concrete Grid Pavers

1.2 Problem statement

The porosity of pervious pavements is provided by omitting all or most of the fine aggregates which impart the necessary percolation characteristics to the concrete. In 2001 the American Concrete Institute (ACI) formed committee 522, "Pervious Concrete", to develop and maintain standards for the design, construction, maintenance, and rehabilitation of pervious concrete. This recent interest in porous surfaces as a substitution for impervious surfaces can be attributed todesirable benefits such as stormwater retention, which includes stormwater treatment. Because of the high void content PCPC generally has low strength (800-3000 psi) which limits applications in cold weather regions and is responsible for various distresses and pavement failures. The need to develop a high performing pervious concrete specification for Maryland conditions was the basis of this report. Several admixtures were tested along with regional materials often used in SHA projects. Structural and durability characteristics were measured against a control mix.

II. MATERIALS USED

2.1 Constituents of concrete

If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. The selection of materials and choice of method of construction is not easy, since many variables affect the quality of the concrete produced, and both quality and economy must be considered. The characteristics of concrete should be evaluated in relation to the required quality for any given construction purpose. The closest practicable approach to perfection in every property of the concrete would result in poor economy under many conditions, and the most desirable structure is that in which the concrete has been designed with the correct emphasis on each of the various properties of the concrete, and not solely with a view to obtaining of maximum possible strength.

2.1.1 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 `1 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 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 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.

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Chemical compounds of Portland cement

The raw material used in the manufactures of Portland cement comprises four principal compounds. These compounds are usually regarded as the major constituents of cement and tabulated with their abbreviated symbols

Table 2.1:Typical composition of ordinary Portland cement

Name of the compound	Oxide composition	Abbrevation
Tricalcium silicate	$3CaOSiO_2$	C_3S
DiCalcium silicate	$2CaO.SiO_2$	C_2S
TriCalcium aluminate	$3CaO,A12O_3$	C_3A
Tetracalcium aluminoferrite	$4CaOAl2O_3$, $Fe2O_3$	C_4AF

These compounds interact with one another in the kiln to form a series of more complex products. Portland cement is varied in type by changing the relative proportions of its four predominant chemical compounds and by the degree of fineness of the clinker grinding. A small variation in the composition or proportion of its raw materials leads to a large variation in compound composition Calculation of the potential composition of Portland cement is generally based on the Bogue composition (R.H Bogue).In addition to the main compounds, there exist minor compounds such as MgO, TiO_2, K_2O and Na_2O; they usually amount to not more than a few percent of the mass of the cement. Two of the minor compounds are of particular interest the oxides of sodium and potassium, K_2O and Na_2O,known as the alkalis. They have been found to react with some aggregates; the products of the reaction causing disintegration of the concrete and have also observed to affect the rate of gain of strength of cement. Present knowledge of cement chemistry indicates that the major cement compounds have the following properties. 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.

III. WHY DO WE NEED PERVIOUS CONCRETE?

A 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, lakes, and coastal waters 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 or asphalt, 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. In many cases, pervious concrete roadways and parking lots can double as water retention structures, reducing or eliminating the need for traditional storm water management systems such as retention ponds and sewer tie-ins Pervious concrete also naturally filters water from rainfall or storm and can reduce pollutant loads entering into streams, ponds and rivers. So in this way it helps in ground water recharge. It also reduces the bad impact of urbanization on trees. A pervious concrete ground surface allows the transfer of water and air to root systems allowing trees to flourish. For a given rainfall intensity, the amount of runoff from a pervious concrete pavement system is controlled by the soil infiltration rate and the water storage capacity available in the pervious concrete and aggregate sub base under the pervious concrete. Generally for a given set of materials, the strength and infiltration rate of pervious concrete are a function of concrete density. Greater the density, higher is the strength and lower the infiltration rate.

Figure 3.1: When it rains, it drains

IV APPLICATIONS OF PERVIOUS CONCRETE

Permeable paving systems are appropriate for parking areas, parking lots, drive aisles, private alleys, sidewalks, courtyards and plazas. Pervious concrete is also known as porous concrete. Porous pavement may substitute for conditional pavement on parking areas, areas with light traffic, and the shoulders of airports taxiways a runways, provided that the grades , subsoils, drainage characteristics, groundwater conditions are suitable. Slopes should be flat or very gentle soils should have field verified permeable greater than 1.3 cm (0.5inch)per hour and there shoukd be 1.2m(4 foot)minimum clearance from the bottom of system to bedrock or the water table. Here the advantages of the pervious concrete as follows: The advantages of using pervious or porous pavement include:

- Water treatment by pollutant removal.
- Less need for curbing and storm sewers.
- Improved road safety because of better skid resistance.
- Recharge to local aquifiers.
- It can be designed in streets as parking and pavement.
- It also can be used for increasing ground water table levels.
- Pervious concrete is also used for developing the irrigation by storing the storing beside the pervious pavements thorough the pipes which are connected under the pavements.
- Pervious concrete saves trees by providing both AIR and WATER to the tree roots. This allows the trees to thrive and reduces tree-root lifting of the pavement.

The use of porous pavement may be restricted in cold regions, arid regions or regions with high wind erssion rates, and the areas sole-source aquifiers. The use porous pavement is highly constrained requiring deep permeable soils restricted traffic, and adjacent land uses. Some specific disadvantages

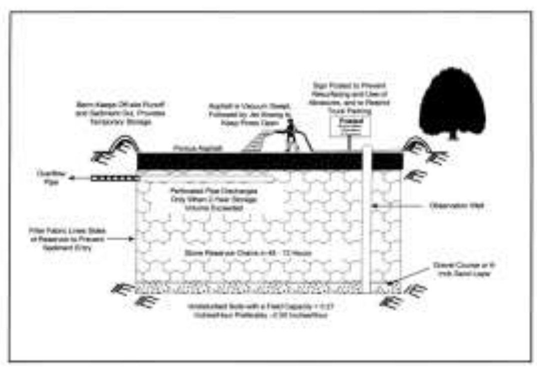

Figure 5.1: Typical porous pavement installation

V. COST

Several factors influence the overall cost of pervious concrete:

1. Material availability and transport - The ease of obtaining construction materials and the time and distance for delivery.

2. Site conditions - Accessibility by construction equipment, slope, and existing buildings and uses.

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3. Subgrade - Subgrade soils such as clay may result in additional base material needed for structural support or added storm water storage volume.

4. Storm water management requirements - The level of control required for the volume, rate, or quality of storm water discharges will impact the volume of treatment needed.

5. Project size - Larger pervious concrete areas tend to have lower per square foot costs due to construction efficiencies.

Costs vary with site activities and access, pervious concrete depth, drainage, curbing and under drains (if used), labor rates, contractor expertise, and competition. The cost of the pervious concrete material ranges from 100 rupees to 350 rupees per square foot. The material cost of pervious concrete can drop significantly once a market has opened and producers have made initial capacity investments. Eliminating or reducing the use of admixtures, which are a significant cost in construction, can also lower installation costs.

VI EXPERIMENTAL TEST AND VALUES

Density and Void Ratio Test

ASTM C1688 has become one of the few accepted tests that can adequately determine effective pervious concrete mix properties such as density and void content. This test helps to determine if the freshly mixed concrete will achieve the targeted void content as specified in the mix design. By first obtaining a cylindrical steel container with a minimum capacity of .25 cubic feet. The inside was moistened with a damp towel and excess water was removed from the bottom. The container was then weighed and the weight recorded to the nearest gram. The freshly mixed pervious concrete was scooped into the container and once it was approximately half full, a standard proctor hammer was used to compact the specimen. The hammer was dropped 20 times evenly around the cylindrical area. The container was then filled ¼ of an inch above the top lip. The proctor hammer was used again to compact the specimen using 20 evenly distributed blows. A hand trowel was used to strike off the top surface of the container and a clean towel was used to wipe down the sides. The cylinder was then weighed and the weight recorded to the nearest gram. The weight of the pervious concrete sample was found by subtracting the total weight of the cylinder and sample from the measured weight of the container.

Figure7.1: Apparatus Used for Density and Void Content

The density and void content was found by first determining the theoretical density of the concrete computed on an air-free basis. This is computed by dividing the total mass of all materials batched by the sum of the absolute volumes of the component ingredients in the concrete mix.

Compressive Strength Test

The compressive strength test was performed on all four mix designs. Three cylinders were cast from each mix design and the average of the compressive strength was used as the final number. Four different periods were used to determine the rate at which the cylinders gained strength – Day 7, Day 14, Day 28. The test was performed at a University of Maryland Laboratory. The specimens were removed from the curing box at the day of testing and wiped clean. The diameter of each specimen was measured at the top, middle, and bottom. The average of the three diameters was used to calculate the cross-sectional area. Any specimen having a diameter varying more than 2% of any other measured diameter was not used in the compression test. All the pervious concrete samples met this requirement. The specimens were then placed under the center ring of the compression machine. The test machine used was hydraulically powered. The upper bearing block was stationary, while the lower bearing block moved up to compress the specimen. The upper bearing block was capable of tilting if the top of the specimen was not completely horizontal. Prior to testing, the surfaces of the testing machine were wiped clean. The test cylinder was then placed on the lower bearing block and centered. The load was applied at a rate corresponding to a stress increase between 28 psi/sec and 42 psi/sec. Each specimen was loaded until the load began to decrease rapidly, and a fracture was clearly evident. The maximum load applied was then recorded. The procedure was repeated at the interval of days noted earlier.

Figure 7.2: Pervious Concrete Specimen in Compression Testing Machine

Results Of Experiments Conducted On Materials

1. Cement (53 Grade Ultratech Cement)
- ♣ Specific gravity : 3.02
- ♣ Fineness of cement : 3.15
- ♣ Consistency : 35%
- ♣ Initial setting time : 120min.

Coarse Aggregate
- ♣ Specific gravity : 3.00
- ♣ Bulk density : 1.50

Fine Aggregate
- ♣ Specific gravity : 2.63
- ♣ Fineness modulus : 2.5

COMPRESSIVE STRENGTH

AGE	W/C RATIO	AGG/CEMENT RATIO	LOAD (TONNES)	COMPRESSIVE STRENGTH (Kg/sq.cm)
7	0.4	6:1	8	35.56
7	0.4	8:1	5	22.22
7	0.4	10:1	4	17.78

Table 7.1: Compressive strength at 7 days for 6:1,8:1 and 10:1 agg/cement ratio and agg. size of 20mm

PERMEABILITY

Agg/cement ratio	W/C Ratio	Coefficient of permeability (sec*10^3)
6:1	0.4	3.2
8:1	0.4	3.5
10:1	0.4	3.65

Table 7.2: Permeability for 20mm aggregates for different w/c ratio

Agg/cement ratio	W/C Ratio	Coefficient of permeability(cm/sec*10^3)
6:1	0.4	1.6
8:1	0.4	2.5
10:1	0.4	3.14

Table 7.3: Permeability for 10mm aggregates for different w/c ratio

VII CONCLUSIONS

Although limited in its applications, pervious concrete has the potential to help mitigate many of the urban stormwater quality issues. Lack of extensive research on pervious concrete has led to some misunderstanding and narrow focus on the use of pervious concrete. One of the objectives of this research was to develop a preliminary pervious concrete specification for Maryland conditions. Several admixtures have been tested as part of this research with the objective of increasing strength, durability and workability of pervious concrete. Improved strength, durability and workability would lead to a wider application of pervious concrete. The types of admixtures that were tested as part of this research included delayed set modifier, viscosity modifier, and cellulose fibers. These three admixtures were selected based on the potential of increasing strength, durability, workability, or a combination of the three. The ability to discharge, place, and finish pervious concrete within a relatively short time span is a major concern for concrete producers. The relatively short working time window with pervious concrete often leads to a very fast paced, labor intensive effort. Incorporating a delayed set modifying admixture into the pervious concrete mix design inevitably allows a longer working window for placement. Pervious concrete is a harsh mix because it contains little or no fine aggregates. Viscosity modifiers have been developed to add body and help lubricate pervious concrete mixes. Better discharge and easier placement and compaction of an otherwise dry, harsh mix have been the key benefit with using VMA's. Viscosity modifiers alter the rheology, or flow behavior, of a concrete mix; each VMA can have a differing effect on the mix based on its specific chemistry. Some VMAs have been used in pervious concrete with less than desirable results. Certain VMAs work by binding water in a concrete mix, thereby changing its viscosity. Cellulose fibers have been gaining popularity as an alternative for polypropylene fibers. It is a green product and has been gaining a lot of attention. Modern cellulose fibers are based upon a virgin, purified form of the cellulose fiber. Cellulose fibers have some significant advantages in addition to being a renewable source of material. They contribute to reduction in shrinkage and temperature cracking, and fiber balling.

The mixtures with higher aggregate/cement ratio 8:1 and 10:1 are considered to be useful for a pavement that requires low compressive strength and high permeability rate.

Finally, further study should be conducted on the pervious concrete pavement produced with these material proportions to meet the condition of increased abrasion and compressive stresses due to high vehicular loading and traffic volumes.

VIII RESULTS

Pervious concrete made from coarse aggregate size 10mm has compressive strength of 48.89kg*cm-2 and 20mm aggregate has 35.56kg*cm^{-2}

Pervious concrete made from coarse aggregate size 20mm had compressive strength value of 74% compared to that of 10mm.

The aggregate/cement ratio of 10:1 produced pervious concrete of higher co-efficient of permeability of 3.14x10-3cm/sec and 3.65x10- 3cm/sec for aggregate size 10mm and 20mm respectively.

VIII PERVIOUS CONCRETE IN INDIA

Pervious concrete can be used and it is being implemented in some metropolitan cities in parking lots, drive ways, gullies, sidewalks, road platforms etc. The roads around the apartments and the surfacing inside the compound can be made with pervious concrete. Another significant advantage in India is low cost of labour compared to western countries, much of the pervious concrete is laid manually without using heavy machinery, so this can be placed in lower costs even in rural areas. In future with increased urbanization, diminishing ground water levels and focus on sustainability technologies such as pervious concrete are likely to become even more popular in India compared to other countries.

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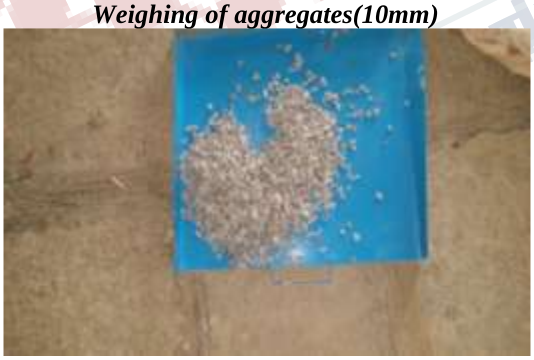
Experimental Work

Weighing of cement(Ultra tech)

Weighing of aggregates(10mm)



Aggregate of 10mm

Mixing of pervious concrete with little sand

Cube mould(150mm X 150mm X 150mm)

Moulding after mixing the Pervious concrete.

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Moulding the pervious concrete after greecing the mould to easy removable of cube.

Testing of Cube that water will pass through the Cube clearly.

Compacting the concrete into

Weighing of cube.