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TO PERVIOUS CONCRETE: A SUSTAINABLE CHOICE IN CIVIL ENGINEERING AND CONSTRUCTION

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Abstract

Pervious concrete, sometimes referred to as no-fines, gap-graded, permeable, or enhanced porosity concrete, is an innovative approach to controlling, managing, and treating storm water runoff. When used in pavement applications, pervious concrete can effectively capture and store storm water runoff, thereby allowing the runoff to percolate into the ground and recharge groundwater supplies. The first pervious concrete has been used in Europe and the United Kingdom since 1930s for the building of single story and multi-storey houses, but had found little acceptance in rest of the world. In recent years, however, due to increased awareness of the need for conservation of non-renewable mineral resources, increased consideration is being given to the use of pervious concrete in most countries. Even though, it is not yet widely used in India, pervious concrete is generally used for light-duty pavement applications, such as residential streets, parking lots, driveways, sidewalks, channel lining, retaining walls and sound walls.This paper discuss the art of pervious concrete; materials and possible mix proportions, properties such as compressive strength, flexural strength, shrinkage, and the principal advantages, major disadvantages and principal applications in Indian construction industry.

Index Terms: *Pervious Concrete, Porosity,Pavement, Storm Water..*

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1. INTRODUCTION

Today in the present world we are very much found of sustainable and eco-friendly source of construction. Particularly in a country like India where flooding and water logging problems are the major environmental issues sustainable development has become a necessity. Various sustainable and eco-friendly means are being implemented to tackle these problems where No-fine concrete pavement is one among them. Working on, rain-drain‟ concept No-fine concrete allows a substantial amount of storm water to seep into the ground, thereby recharging the groundwater and reducing the storm water runoff. No-Fines Concrete is a light-weight concrete produced by omitting the fines from conventional concrete. No-fines concrete is a concrete consisting of cement, coarse aggregate and water. It has its origin in late 1940s and now been viable used in United States, Japan and Europe because of its various environmental benefits such as controlling storm water runoff, re-establishing groundwater supplies and reducing water and soil pollution. Apart from this it has potential to reduce urban heat island effects and can be used to reduce acoustic noise in roads. No-fines concrete is usually made with aggregate/binder ratio of 6: 1 to 10: 1. Coarse aggregates used are generally of size passing through 20 mm and retained on 10 mm. The water/cement ratio for satisfactory consistency varies between a narrow range of 0.27 and 0.43. The 28-days compressive strength ranges from 5.6 to 21.0 Mpa, with porosity ranging from 14 to 31%, and permeability coefficient varies from 0.25 to 6.1 mm/s. The effects of aggregate-cement ratio, aggregate sizes and type of binder material on strength of No-fine concrete have been reported in the past Pioneering research on No-fine concrete has been carried out worldwide for the past few years to make it suitable for major pavement application works

1.2 Main Objectives of Pervious Concrete

1. To help restore ground water supply.
2. Reduce pollution of coastal water.
3. Recharge ground water table.
4. Reduces runoff water.
5. Reduces risk of flooding and topsoil wash away.

1.3 Basic Principle

In pervious concrete the most important and basic principal which turns out to be different from other types of concrete like PCC and RCC because, it has no fine aggregates in it. Pervious concrete also has interconnected voids and because of that water will percolate and spread in all direction which is not possible if those joints are not interconnected.

1.4 Typical Composition Of Pervious Concrete

Pervious concrete sometimes referred to as “no-fines concrete” is a mixture of hydraulic cement, coarse aggregate of smaller size, admixtures and water. Normally, pervious concrete does not contain any sand and its air void content varies between 15 and 30%. A small amount of sand can be used for compressive strength improvement but air void content will be reduced and permeability lowered.

Figure 1. Pervious Concrete

2. LITERATURE SURVEY

2.1 Materials:

2.1.1 Constituents of Concrete

If a constituent is to be suitable for a particular purpose, it is necessary to select the 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.

2.1.2 Cement

Ordinary Portland cement of 53 grade conforming to IS: 269 – 1976. Ordinary Portland cement, 53 grade was used for casting all the specimens. Various types of cement also will produce concrete have a different rates of strength development. The choice of grade and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strength at early ages can be considerably influenced by the particular cement used.

2.1.3 Coarse Aggregate

Locally available crushed blue granite stones aggregate of nominal size 12.5 mm as per IS: 383-1970. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite.

2.1.4 Water

Casting and curing of specimens done with the portable water which is available. The control of water is important in the development of pervious concrete mixtures. The control of water is very important in the development of pervious concrete mixtures, and the selection of an appropriate w/cm value is important for obtaining desired strength and void structure in the concrete. A high w/cm can result in the cement paste flowing off of aggregate and filling the void structure, whereas a low w/cm can result in mixing and placement difficulties and reduced durability. Commonly, w/cm values between 0.27 and 0.34 are used.

2.1.5 Admixtures

As with conventional concrete, chemical admixtures can be used in pervious concrete to obtain or enhance specific properties of the mixture. Set retarders and hydration stabilizers are commonly used to help control the rapid setting associated with many pervious concrete mixtures. Air-entraining admixtures are required in freeze–thaw environments although no current method exists to quantify the amount of entrained air in the fresh paste. Air entrainment can be determined on hardened samples according to ASTM C457

2.1.6 Silica fume

Silica fume is a by-product in the carbothermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume is also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. Silica fume is an ultrafine material with spherical particles less than 1μm in diameter, the average being about 0.15μm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume is depend on the degree of densification in the silo and varies from 130 to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. Silica fume available at KGR Fusion, Ludhiana has been used in the present study.

2.1.7 Super Plasticizer

Super plasticizersare also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation and to improve the flow characteristics of suspensions such as in concrete applications. This effect drastically improves the performance of the hardened fresh paste. Cicoplast super is used for producing extremely flow able concrete, pumped concrete, pre-stressed and denser concrete as well as in industrial commercial flooring and floor toppings. Cicoplast super is new generation concrete admixture based on modified Sulphonated naphthalene formaldehyde, combining the properties of super plasticizers with high degree of slump retention characteristics, high range water reducer and also acts as water proofers for concrete, confirms to ASTM C-494.

3.0 STUDY EXPERIMENTAL PROGRAMME

3.1 Methodology

The mix proportioning procedure for No-fine concrete done according to "Guide for selecting proportions for no slump concrete" reported by ACI committee 211.3R-02.The method is based on the volume of paste necessary to bind the aggregate particles together while maintaining the necessary void content. the paste volume should be reduced by 2% for each 10% fine aggregate of the total aggregate for well-compacted No-fine concrete, and by 1% for each 10% fine aggregate of the total aggregate for lightly compacted No fine concrete. These reductions are necessary to maintain the same percent voids by volume.

3.2 Material Preparation

Specimen constituents should be prepared before mixing in order to produce pervious concrete. Portland cement type II and V , water, coarse aggregate, fine aggregate (nature sand) up to 2% fine sands by weight, fibre, Air Entrainment, Mid-range Water Reducer, Hydration Stabilizer, Viscosity Modifier, and silica fume. Admixtures were used in the mix design to improve the strength of pervious concrete mixes. Using some ready admixtures such as Micro Air, air-entraining admixture, is recommended because it provides more protection for the concrete by generating small, strong and closely spaced air bubbles. It also decreases the internal stresses caused by expansion and contraction of water in the concrete pores upon freezing and melting during a daily cycle.

3.3 Specimen Production

A series of pervious concrete mixes are created when specimen production was needed. The mixes include three different sizes of coarse aggregate. The mixes have different ratios of each kind of aggregate and sometimes they were not included in the mix. The mixes also incorporated at a rate of 2% by weight. Water and cement are added into the mix with a water to cement ratio of 27%. Four different admixtures in liquefied forms are added to the mix with each having their influence on the performance of the specimens. Moreover, some of the mixes have fibre mesh 150, which is a micro reinforcement system for concrete. For this phase, a new admixture is added to mix, which is silica fume. Silica fume is different from the other four admixtures in being in solid powder form. For each mix design formula, four specimens are made. For this project, the volume is considered for five specimens in case of any mistakes taken through the mixing procedure.

3.4 Pervious Concrete Mixture Development

To ensure good performance during both the construction and service periods, a pervious mixture for a pavement overlay must possess the following properties:

1. High workability for ease of placement
2. Uniform porosity or void structure throughout the pavement for noise reduction
3. Adequate bond with underlying pavement and proper strength for traffic load

A systematic study using a large number of mix designs was conducted to investigate effect of a wide variety of concrete materials and mixture proportions on pervious performance, including concrete workability, compaction density, strength, freeze-thaw durability, and overlay bond strength. The results indicate that Pervious mixtures can be designed to be highly workable, sufficiently strong, permeable, and with excellent freeze-thaw durability, suitable for pavement overlays. Such overlays will not only function well structurally for carrying designed traffic loads but also perform well environmentally for noise reduction, skid resistance, and splash.

3.5 Curing & Surface Durability

Concrete curing is required to maintain maximum moisture to allow cement hydration and concrete microstructure development, and curing has been shown to impact concrete durability and strength. While many techniques exist to control moisture loss in traditional concrete, most are not appropriate for pervious concrete. Curing is particularly important for pervious concrete because the high porosity and bottom exposure of the slab may allow rapid loss of moisture from the fresh concrete due to evaporation. The current method of curing PCPC involves covering the fresh concrete with plastic sheets and allowing the pavement to cure for seven days before removal of the plastic. The effect of different curing methods or curing materials was evaluated for effect on pervious concrete properties, including flexural strength and surface abrasion resistance. The samples cured under plastic had the best abrasion and resistance as well as the highest flexural strength, and it was shown that seven days of curing was sufficient for strength gain. As compare to other methods, soybean oil has the potential to be an effective curing compound, supplementing or possibly replacing plastic. Additional studying of curing methods will be necessary for large-scale use of pervious concrete in roadway applications and as new products and techniques emerge.

4.0 TESTS ANALYSIS

4.1 Tests Study

There are three tests that need to be conducted to determine the best mix design formula. They are: Compressive Strength, Void Ratio and Freeze-Thaw Cycle. Each test has its steps in order to find the results.

4.1.1 Compressive Strength

The Compressive Strength Test determines how much pressure a specimen can withstand. For this test, a cylindrical specimen is needed. The specimens created had a four inch diameter and the height of eight. The specimens were placed in the machine and the pressure is applied until the specimens failed and a screen shows the maximum applied pressure.

4.1.2 Void Ratio Test

The Void Ratio Test measures the void ratio of the specimen. After completing the Void Ratio, the porosity also known as void ratio can be calculated using the following equation:

$$P= [1- (w_2 - w_1) / (\rho_{w*}vol.)]100(\%) \text{ - Equation 1}$$

4.1.3 Freeze Thaw Cycle Test& Result

The Freeze-Thaw Cycle Test measures how many cycles a specimen can withstand before cracking. The specimen is made into a rectangular shape. The length of the specimen is 16 inches while the base and height of the specimen are four by four. The machine will run cycles on the specimens placed inside with a low temperature of -18°C and a high temperature of 4°C. Flagstaff, Arizona usually experiences around 250 cycles per year. Therefore, the specimens are required to withstand at least 250 cycles and the testing will last till 300 cycles.The team placed the specimens inside the freeze-thaw cycle machine in November 2014. The test is currently running the 100th cycle and none of the specimens being tested had failed. The test finishes when the specimens either fail or last until the 300th cycle. The late testing was due to being late with producing the best mix design formula. When the best mix design formula was produced, the freeze-thaw cycle test started.

4.5 TESTING RESULTS

4.5.1 Compressive Strength Test Results

The compressive strength results varied due to different kinds of aggregate were used in the mix design formulas. The group members brought aggregate for the city of Camp Verde, Arizona and the results were not consistent. This is because the coarse aggregate from Camp Verde is a combination of Basalt, Limestone, Quartzite, and Granite. Each kind of rock has different characteristics in terms of compression strength. Therefore, the members brought aggregate from the city of Prescott, Arizona. The results came out to be very consistent. This is because the coarse aggregate was mainly Basalt. The specimens created were tested on the 7th and 28th days of curing. The first mix starts with the number 25 as it is the 25th mix formula from the start of the project. CV means that the aggregate is from the city of Camp Verde, AZ and PR means that the aggregate is from the city of Prescott, AZ. Table 1 shows the compressive strength results for the specimens with or without silica fume and fibre. The mix design formula 31 was chosen as it resulted in the highest compressive strength.

Table No. 1 Compressive Strength Results: Specimens with/without Silica Fume &Fiber

Mix Number	Test Result			
	7-day Comp.(psi)		28-day Comp.(psi)	
31 Fibre/SF	2150	2229	2389	2477
31 Fibre	2492	2548	2673	2708
31 SF	3362	3424	3495	3554
31 Fibre/SF	3838	3933	4154	4033

4.5.2 Void Ratio Results

After completing the ASTM C127 procedure, the void ratio results were obtained for the specimens produced the results. The team's goal is to have a porosity ratio higher than 17%. Most of the specimens were tested on the 28th day of curing and that's why no results were found for the other two specimens on the formulas (25 CV- 31 PR). The last two formulas have the four specimens testing results (16 PR and 31 PR). Some of the specimens tested had a lower void ratio than 17%. This might be because the smaller size aggregate, either 12mm or 12.5mm", had a high percentage in the formula and that caused the voids to close more than needed. Table 2 shows the porosity results for the specimen with or without silica fume and fibre

Table 2: Porosity Test Results for Specimenswith/without Silica Fume and Fibre

Mix Number	Porosity (%)			
	Sample 1	Sample 2	Sample 3	Sample 4
31Fibre/SF	20.8	20.9	20.4	21.8
31 Fibre	21.6	21	19.3	21.9
31 SF	18	19.2	18.3	18.8
31Fibre/SF	20	19.1	19.4	18.8

5. Applications of Pervious Concrete

Pervious is normally used without any reinforcement due to high risk of corrosion because of the open pores in its structure. Some applications of PCPC include pervious pavement for parking lots, rigid drainage layers under exterior areas, greenhouse floors to keep the floor free of standing water, structural wall applications where lightweight or more better thermal insulation characteristics, or both are required, elements where better acoustic absorption characteristics are desired, base course for roads, surface course for parking lots, tennis courts, zoo areas, animal barns, swimming pool decks, beach structures, seawalls, embankments, etc.

6. CONCLUSIONS

1. Compressive strength of pervious concrete depend upon the porosity of concrete, binder material, test specimen shape and size, showed huge influence on the strength of pervious concrete .
2. Testing results show that the admixture, silica fume, had increased the compressive strength of the specimens. This helps the specimens to withstand under higher pressure if applied on the pavement

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