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Experimental Investigation on Pervious Concrete as an Environmental Solution for Pavement

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ABSTRACT

Pervious concrete is considered to be an advanced pavement material in terms of the environmental benefits arising from its basic feature high water permeability. This paper presents the results of experimental work that is aimed at testing technically important properties of pervious concrete prepared with three different water-to-cement ratios. The following properties of pervious concrete were tested compressive and splitting tensile strength, unit weight at dry conditions, void content, and permeability. The mix proportions were expected to have the same volume of cement paste, and, to obtain the same 20% void content for all of the samples. The results show that changes of water-to-cement ratio from 0.35 to 0.25 caused only slight differences in strength characteristics. Arising tendency was found in the case of compressive strength and a decreasing tendency in the case of splitting tensile strength. The hydraulic conductivity ranged from 10.2 mm/s to 7.5 mm/s. The values of both the unit weight and void content were also analyze to compare the theoretical (calculated) values and real experiment results. A fairly good agreement was reached in the case of mixtures with 0.35 and 0.30 water-to-cement ratios, while minor differences were found in the case of 0.25 ratio. Finally, a very tight correlation was found between void content, hydraulic conductivity and compressive strength.

***Key Words*:pervious concrete; water to cement ratio; strength; hydraulic conductivity; void content**

I. INTRODUCTION

People change the natural environment when they build buildings and roads. One of the most notable changes is connected with the construction of impervious areas in places that were originally permeable. Impervious areas prevent water from infiltrating the soil underneath. Examples of impervious areas include rooftops, parking lots, and roadways. The environment is adversely affected by the integration of impermeable areas into the surface this fact causes disruption of the natural water cycle. It consequently causes the blocking of the natural process of water infiltration through the soil thus, in the case of storm events and snowmelts, the water runoff from the impervious surfaces are very fast. There are three main aspects of this runoff, as given in : a decrease in groundwater recharge due to lack of infiltration, alteration in the natural flow patterns of a drainage basin, and transportation of contaminants, deposited on impervious surfaces, to receiving water bodies". This is the way how the interruption of both surface and subsurface water quantity and quality is affected . With development of new urban areas, there is a great challenge in finding new ways to manage storm water runoff. Among others, porous pavements are presented as an alternative method for storm water control.

Types of porous pavements include porous asphalt, pervious cement concrete, concrete paving blocks, gravel paving systems, and grass paving systems, among others. According to , the way how the pervious pavements work lies in reduction of runoff volume by allowing for water to pass through them, be stored, and subsequently be released into the ground. Focusing on the pervious concrete, it can be described as a material consisting of open-graded coarse aggregate, Portland cement, water, and admixtures. The basic arrangement of composition contains mainly characterization of the aggregate: size of approximately 8 mm; sand is neglected to leave the space between grains empty. A representative pervious concrete has 15% to 25% of void space. The consistency of pervious concrete mixtures is characterized by little to no slump This inherent property is due to the low cement-paste content, allowing the creation of only a thin film coating the aggregate. High-viscosity paste is needed to coat the aggregates, while resisting the drain down of the paste. The mitigation of drain-down is pertinent for the matrix porosity to be maintained across the width of the concrete section. The structure relies on the stone-to-stone contact achieved through compaction, which allows for the cement-paste-coated aggregates to bond with one another. To achieve the proper void structure, it is recommended to use the appropriate cement paste, which should possess a low water-to-cement (w/c) ratio of about 0.20 to 0.25, in addition to super plasticizer and adequate mixing. The experiment given in shows a decrease in compressivestrength with a decrease in w/c ratio, which is unlike the conventional dense-concrete behavior. Another experiment shows a w/c ratio that ranges from 0.2 to 0.4. They report that pervious concrete mixtures with w/c ratios under 0.3 require water-reducing admixtures while those with w/c above 0.3 can be mixed without plasticizer. In general, w/c in the range of 0.27–0.34 can be assumed as the most common and wide range applicable for pervious concrete mixtures.

Another options of pervious concrete involve the improvement of water quality in ground water recharge . Due to the storm-water runoff infiltration into the ground, the sediment is filtered and contaminants do not pass into the groundwater. Similarly, due to water infiltration through the concrete layer, pervious concrete parking lots can serve as recharge basins. Other benefits of pervious concrete are following: better road safety because of increased skid resistance, road sound dampening, and a reduction of the “heat island” effect. This article presents a study that has been conducted to confirm the applicability of the w/c ratio in the range of 0.35–0.25 for locally available concrete components. The influence of w/c ratio on the key properties of pervious concrete was evaluated in terms of the following properties: compressive and splitting tensile strength, unit weight, void content, and hydraulic conductivity. The void content was assumed as constant, and, together with unit weight, was controlled for comparing the theoretical values and real experiment results. The results were also analyzed in terms of the dependence of the key properties. The specifications of correlation are given as well.

II. LITERATURE REVIEW

Malhotra : (1976) found that the density of no-fines concrete is generally about 70 percent of conventional concrete when made with similar constituents. The density of no-fines concrete using conventional aggregates varies from 1602 to 1922 kg/m3. A clinker aggregate was trailed and the no-fines concrete produced a density of 961 kg/m3. Adequate vibration is imperative for strength of conventional concrete. The use of no-fines concrete is different and is a self-packing product. Malhotra (1976) suggests that the use of mechanical vibrators and ramming is not recommended with no-fines concrete. A light rodding should be adequate and used to ensure that the concrete reaches all sections of the formwork. This is not a problem with conventional concrete since it has greater flow ability than no-fines concrete. The light rodding ensures that the concrete has penetrated all the areas impeded by reinforcing steel. Malhotra (1976) stresses that in situations where normal conditions are not achieved during placement and curing, the formwork should not be removed after 24 hours as with conventional concrete. No fines concrete has very low cohesiveness and formwork should remain until the cement paste has hardened sufficiently to hold the aggregate particles together. However, this is more of a consideration in low temperature conditions and when used in non-pavement applications where the concrete is not sufficiently supported by the ground or other means.

Ghafoori et al : (1995) Undertook a considerable amount of laboratory investigation to determine the effectiveness of no-fines concrete as a paving material. The curing types were investigated to determine if there was any difference between wet and sealed curing. There appeared to be only a negligible difference in strength between the different curing methods. It was clear from the test results that the strength development of no- fines concrete was not dependent upon the curing conditions. The indirect tensile test conducted by Ghafoori (1995) found that the sample tests varied between 1.22 and 2.83MPa. The greater tensile strength was achieved with a lower aggregate-cement ratio. Ghafoori et al (1995) explained the more favourable properties obtained by the lower aggregate-cement ratio by an improved mechanical interlocking behaviour between the aggregate particles.

Abadjievaet al : Determined that the compressive strength of no-fines concrete increases with age at a similar rate to conventional concrete. The no-fines concrete specimens tested had aggregate-cement ratios varying from 6:1 to 10:1. The 28 day compressive strength obtained by these mixes ranged from 1.1 and 8.2 MPa, with the aggregate-cement ratio of 6:1 being the strongest. He concluded that the most plausible explanation for the reduced strength was caused by the increased porosity of the concrete samples. This strength is sufficient for structural load bearing walls and associated applications. Ghafooriet al (1995) produced no- fines concrete with a compressive strength in excess of 20 MPa when using an aggregate-cement ratio of 4:1. Abadjieva et al investigated the influence of the aggregate-cement ratio on the tensile and flexural strength of no-fines concrete. This study only assessed aggregate-cement ratios ranging from 6:1 to 10:1. The highest strengths were obtained with an aggregate-cement ratio of 7:1 and the strength decreased with an increasing aggregate-cement ratio. He found that the tensile and flexural strengths of no-fines concrete were considerably lower than those obtained from conventional concrete, but he could not explain why the sample with the highest strength had a ratio of 7:1.

Krishna Raju : A study conducted by Krishna Raju(1975) focused on the optimum water content for no-fines concrete. It was determined that for the particular aggregate-cement ratio there is a narrow range for optimum water-cement ratio. This water-cement ratio was imperative to gain the maximum possible compressive strength. A higher than ideal water-cement ratio would cause the cement paste to drain from the aggregate particles. Alternatively, a water-cement ratio too low would stop the cement paste from adhering sufficiently to the aggregate. When the optimum water-cement ratio was not obtained, sufficient compaction could not be achieved, further compounding the loss of compressive strength.

The large air voids in no-fines concrete does not allow water to penetrate using capillary action. Malhtora (1976) noted that the depth of penetration in no-fines concrete by this method under conditions of high humidity and no air movement is generally no greater than two or three times the largest aggregate diameter. The penetration of moisture was higher in no-fines concrete made from conventional aggregates than clinker aggregate.

III. MATERIAL PROPERTIES

3.1. CEMENT

Portland cement and supplementary cementitious materials are often used in Portland cement pervious concrete. In this project, 53 grade ordinary Portland cement conforming to IS 8112-1989 cement used.

3.2. AGGREGATE

Aggregate grading generally used in PCPC are typically either single-sized coarse aggregate or grading between 9.5 and 19 mm. PCPC made with single-sized aggregate has high permeability, but low strength development. Although aggregate with a maximum size of 37.5 mm has been successfully used, 20-mm maximum size is commonly used. Single-sized aggregate up to 25 mm also has been used.

3.3. SUPERPLASTICIZER

The ConplastSP430 is based on Sulphonated Naphthalene Formaldehyde and is supplied as a brown liquid instantly dispersible in water. ConplastSP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

3.4. CONCRETE

Specific gravity: 1.24 to 1.26

Chloride content: Nil

Air entrainment: Approximately 1% additional air is entrained.

Compatibility: Can be used with all types of cements except high alumina cement. Conplast SP430 is compatible with other types of Fosroc admixtures when added separately to the mix. Site trials should be carried out to optimize dosages.

Workability: Can be used to produce flowing concrete that requires no compaction. Some minor adjustments may be required to produce high workable mix without segregation.

Cohesion: Cohesion is improved due to dispersion of cement particles thus minimizing segregation and improving surface finish.

Compressive Strength: Early strength is increased upto 20% if water reduction is taken advantage of. Generally, there is improvement in strength upto 20% depending upon W/C ratio and other mix parameters.

Durability: Reduction in W/C ratio enables increase in density and impermeability thus enhancing durability of concrete.

Dosage: The optimum dosage is best determined by site trials with the concrete mix which enables the effects of workability, strength gain or cement reduction to be measured. Site trials with Conplast SP430 should always be compared with mix containing no admixture. As a guide, the rate of addition is generally in the range of 0.5-2.0 liters/100kg cement.

IV. TESTS ON HARDENED CONCRETE

4.1. COMPRESSIVE STRENGTH TEST

The compressive strength tests are conducted to ensure a minimum strength is achieved by the particular mix. Cylinder and cube testing are methods of determining the compressive strength. The cylinder testing is an Australian Standard for testing compressive strength, while cube testing is a British Standard**.** The cube test, due to the method by which it is implemented, should give a more stable test specimen than the cylinders. This test will determine the strength of the sample along the entire length of the sample and eliminate problems encountered with the edge aggregate dislodging and failing. The cube method usually determines a concrete strength increased by 10 and 40 percent in comparison to the equivalent cylinder test.

Apparatus:

1. Testing Machine – complying with the appropriate requirements.
2. Bearing Strips – require two tempered grade hardboard, 5 mm thick.

Testing Procedure:

The measuring and testing of test specimens was undertaken as soon as possible after being removed from the water. All specimens were tested in a wet condition and excess water removed from the surface. Dimensions of the test specimens were measured and recorded. The platens were cleaned when necessary to ensure no obstruction from small particles or grit. It was ensured there was no trace of lubricant on the bearing surfaces. The 150 by 150 mm plate was placed on top and bottom of the specimen directly opposite each other. The specimens were centered on the bottom platen of the testing machine. The upper platen was lowered until uniform pressure was provided on the specimen. A force was applied at the required rate shown by the rotating disc on the testing machine. The maximum force applied to the cylinder was recorded and the compressive strength calculated.

Results of Compression Strength:

The maximum compressivestrength determined inthe cube testsis 6.8MPa.

4.2. INDIRECT TENSILE STRENGTH TEST

The tensile strength of concrete cannot be measured directly. This leads to the need to determine the tensile strength through indirect methods. The indirect tensile test is also referred to as the ‘Brazil’ or splitting test, where a cylinder is placed on its side and broken in the compression machine. This test can also be used to determine the modulus of elasticity of the concrete sample.

Apparatus:

1. Testing Machine – complying with the appropriate requirements.
2. Bearing Strips – require two tempered grade hardboard, 5 mm thick.

Testing Procedure:

The diameter of specimen in the plane in which it is being tested as well as the lengths where the bearing strips are in contact were determined. The bearing strips between the testing jig and the test specimen were aligned. The testing jig was centered in the compression machine and the top platen was lowered. The force was at the required rate without shock. The maximum force applied to the concrete before failure was recorded. The fracture type and appearance of concrete was also recorded.

Results of Indirect Tensile Strength Test

The average Indirect tensile strength determined in the prism is 1.03MPa.

V. CONCLUSION

The strength of No fines concrete is lower, then also this concrete is used for road pavement. The compressive strength of no fines concrete is 68.09 % smaller than the conventional concrete at 28 days. The Indirect tensile strength of no fines concrete is 16.44 % smaller than the conventional concrete at 28 days. The workability of No fines concrete is lower than conventional concrete. The cost of No fines concrete is less than conventional concrete, because of omitting the fine aggregate from concrete. No fines concrete is environmental friendly due to absence of river sand. No-fines concrete does not suffer from these inadequacies of standing water, since a large volume of water will be stored instantly within the pavement.

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