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Assessment of Durability of Reactive Powder Concrete Using Oxygen Permeability Index

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Abstract:-Durability of concrete is very important parameter for using natural resources effectively and reducing the cost of reconstruction, maintenance and repair of structure. This paper focuses on need of much of the need for concrete repair can be eliminated, if sufficient consideration and attention is given to control of surface quality of concrete at the construction stage. A South African approach is used to measure the oxygen permeability index testing and concluded that the method is applicable to actual project and is durability index is a parameter to evaluate the durability of RPC and cover zone concrete. RPC shows a good OPI value indicating impermeable concrete and its use can be justified for special purpose.

Keywords:- RPC, OPI Durability, cover zone concrete, durability index.

I. INTRODUCTION

Permeation is the process of movement of fluids through concrete's pore structure under an externally applied pressure, whilst the pores are saturated with the particular fluid. Many tests have been developed to assess the permeability of concrete. These tests are mainly of two types:

Through flow permeability tests try to determine the Darcy coefficient of permeability. This is done by measuring the pressure gradient (flow rate) through concrete under a sustained pressure head. These tests can take a long time and are impractical for dense concretes

Inflow permeability tests measure the depth of fluid penetration after a period of applied pressure. Falling head permeameters apply an initial pressure to a concrete sample and the pressure is allowed to decay as permeation proceeds. This approach maintains a high Level of accuracy since pressure may be reliably monitored with time. Inflow permeability tests are easier to perform than through flow permeability tests here, the falling head gas permeameters test, developed at the University of the Witwatersrand by Ballim is used, a schematic figure of the test apparatus is shown on **Figure 1.0**

The permeability is determined by measuring the pressure decay with time, having the initial pressure value set as 100*kPa*.

The pressure decay observed was converted to a linear relationship by plotting the logarithmic ratio of pressure heads versus time. The slope of the line is the coefficient of permeability. The coefficient of permeability can also be determined by using:

$K = (\omega V g d / R A \theta t) \times (\ln P_0 / P)$

Where k is the coefficient of permeability [*m/s*]

ω is the molecular mass of permeating gas [*kg/mol*]
V is the volume of the pressure cylinder [m^3]
g is the acceleration due to gravity [m/s^2]
d is the sample thickness [*m*]
R is the universal gas constant [*Nm/K mol*]
A is the cross-sectional area of specimen [m^2]
θ is the absolute temperature [*K*]
t is time [*s*]
P_0 is the pressure at the start of the test [*kPa*] and
P is the pressure at time t [*kPa*]

The coefficient of permeability is simplified the by defining the permeability index (OPI): $OPI = -\log_{10}(K)$

II. SCOPE

This test method sets out the procedure for determining the oxygen permeability index as originally described by Alexander, Ballim and mackechnie. The method described herein supercedes the 1999 version in ref. 1 The test is suitable for the evaluation of materials and mix proportions for design purposes, and for research and development. The test can also used for quality control of concrete on site. It is not recommended that this test be performed before 28 days after casting. Specimen age may have a significant effect on the test results, depending on the type of concrete and the curing procedure.

The oven drying procedure has been selected to result in the minimum degree of micro-structure alteration of the concrete specimens, while still giving minimal uniform moisture content. Research has shown, however, that significant amount of micro-structural damage may occur for some high quality concrete notably high strength concrete incorporating silica fume. Thus care should be taken in interpreting the results from these concretes. This test method shall not be used for concrete with a maximum nominal aggregate size exceeding 26.5 mm.

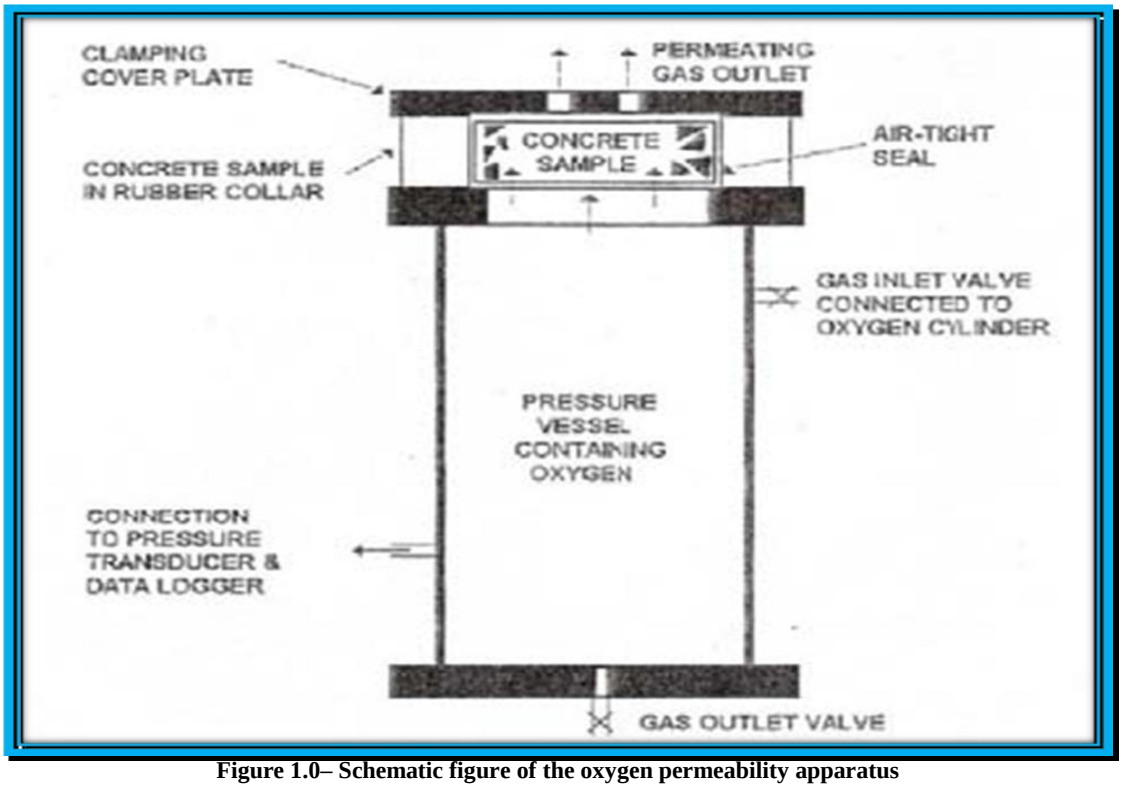

Figure 1.0– Schematic figure of the oxygen permeability apparatus

III. TEST SPECIMEN

Four test specimens are required per test. The test specimen shall consist of a 68±2 mm diameter concrete disc with a thickness of 25mm±2mm core and cut in accordance with concrete Durability Index Testing monograph.

3.1 condition of specimens

Directly after cutting the specimens shall be placed in the oven at 50 ± 2^{o} C for 7days±4 hours.

3.2 testing of specimens

a) Cool the specimens on a steel tray in the desiccators to 23 ± 2^{o} C for no less than 2 hours and no longer than 4 hours. Check the temperature of the specimens to be tested by placing a thermometer between the test faces of the specimens.
b) Directly after removing the specimens from the desiccators mark the specimens of the same reference 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% for normal curried and 1.0H%, 1.5H%, 2.0H%, 2.5H%, and 3.0H% for hot curried water sample.
c) Measure to the nearest 0.02mm the thickness and diameter of each specimen with the vernier at 4 points equally spaced around the perimeter of the specimen, and record. Determine the average of the four readings and record to the nearest 0.02 mm.
d) Place the specimen in the compressible collar with the test face (outer face) at the bottom. No gaps should be visible between the collar and the test specimen.
e) Place the collar in the PVC sheath on top of the collar, once again ensuring that no gapes are visible between the collar and the sheath. Place on the top of the permeability cell.
f) Place the cover plate in position and tighten.
g) Start each test with 30 min ± 5 min after removing the specimen from the desiccators.
h) Open the oxygen inlet and outlet valves of the permeability cells and allow oxygen to flow through the permeameter for 5 seconds. This will purge the test chamber.
i) Close the oxygen outlet valve of the permeability cells.
j) When the pressure rises above 100kPa on the gauge of the permeability cell, close the inlet valve.
k) Tap the gauge to ensure a correct reading. Adjust the pressure in the cell to 100kPa±5kPa by opening the outlet valve slightly. Record the initial time, t_0 to the nearest minute and initial exact pressure, P_0 to the nearest 0.5kPa. This initial pressure shall be within ± 5kPa of 100kPa. Use t_0 and P_0 as such in the calculations.
l) After 5 minutes tap gauge and record the time and pressure reading. if the pressure drops too quickly (> 5kPa per minute),there may be a leak present. In such case, release the pressure in the chamber, check that the sample fits tightly in the collar, and restart the test immediately.
m) Subsequently readings should be taken with sufficient frequency that the pressure has not dropped more than 5kPa±1kPa between readings. For each reading, note the time to the nearest minute and pressure in the test cell to the nearest 0.5kPa.

n) The test may be terminated when the pressure has dropped to 50kPa±2.5kPa or after 6hours±15min, whichever occurs first. A minimum of 8 readings is required.

IV. OXYGEN PERMEABILITY INDEX TEST, OPI

The South African oxygen permeability index (OPI) test method comprises measuring the pressure decay of oxygen passed through a concrete disk placed in a falling head permeameter. A pressure gradient is applied across the test specimen and subsequently the pressure decay in the pressure cell is monitored over time prior to testing, samples are preconditioned by oven drying at 50^{o}C for a period of seven days.

V. RESULTS AND DISCUSSIONS

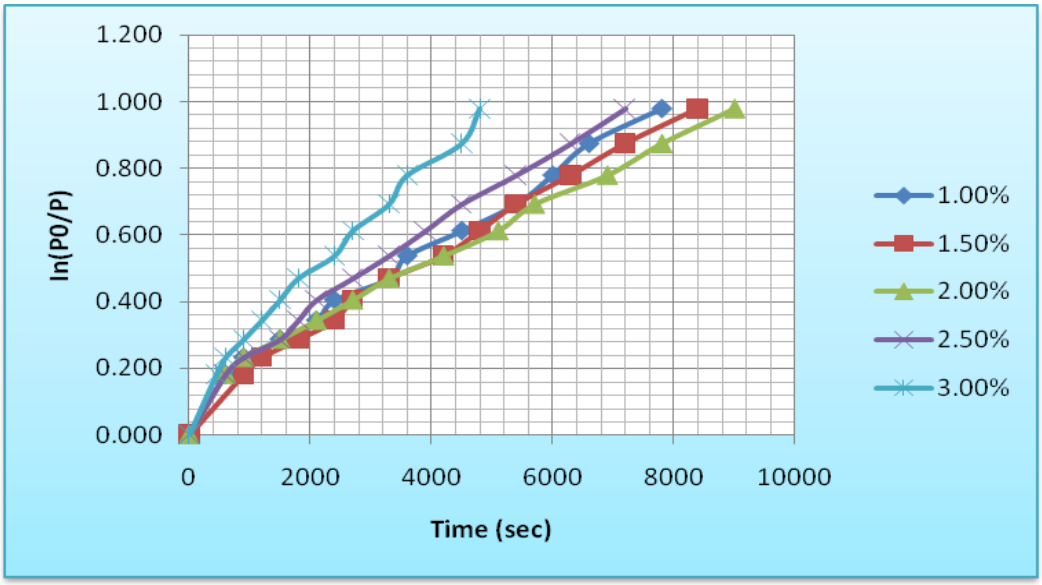

FIG.2.0 PRESSURE DECAY WITH TIME FOR HOT CURING

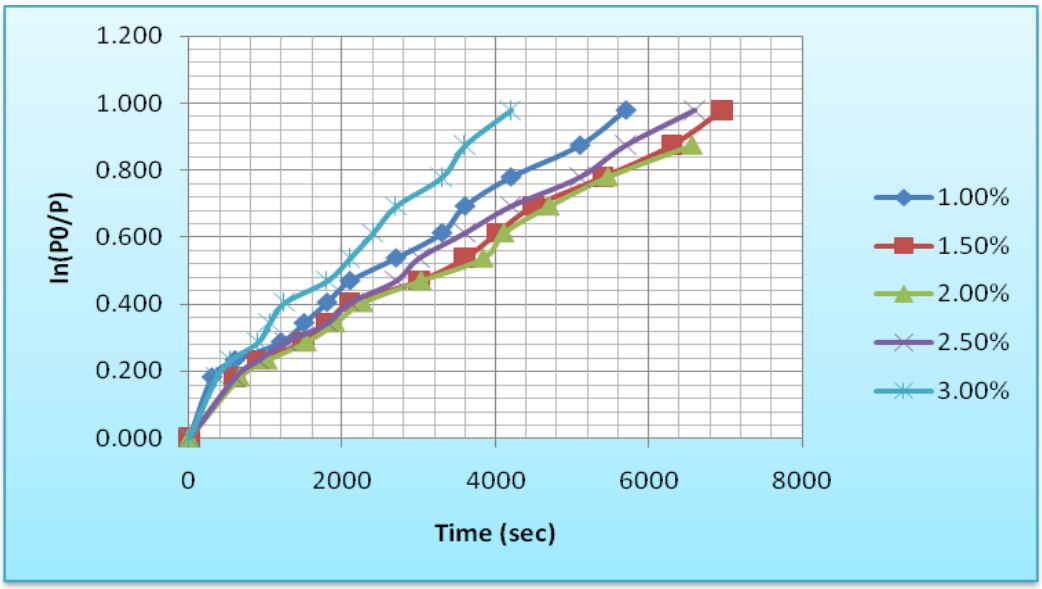

FIG.3.0 PRESSURE DECAY WITH TIME FOR COLD CURING

TABLE 1.0 – SUGGESTED RANGES FOR DURABILITY USING INDEX VALUE.

Durability Class	OPI (log scale)	Sorptivity
Excellent	>10	<6.0
Good	9.5-10	6-10
Poor	9.0-9.5	10-15
Very poor	<9.0	>15

VI. OXYGEN PERMEABILITY

The oxygen permeability index (OPI) gained from the measured samples are listed in Table 9.3.Most of the samples had a permeability index (OPI) between 9 and 9.5, which is classified as concrete with poor permeability properties, according to **Table 2.0**. The entire concrete sample had an average OPI value within this range. Having some variation in the test results is normal as the oxygen permeability test assesses the overall micro- and macrostructure of the outer surface of cast concrete. It is particularly sensitive to macro-voids and cracks, since they act as short circuits for the permeating gas.

TABLE 2.0 OPI OF RPC FOR DIFFERENT CURING

Sample	HOT Curing	NORMAL Curing
Slice	OPI	OPI
1.0% steel fiber	9.13	8.99
1.5% steel fiber	9.16	9.09
2.0% steel fiber	9.18	9.1
2.5% steel fiber	9.08	9.05
3.0% steel fiber	8.92	8.86

The OPI value differed depending on the depth of the cylinder where the measured slice was taken. The OPI value was also found to be dependent on the amount of stratification. All these samples were cast using the same mix design and cured under the different conditions.

VII. CONCLUSIONS

- OPI is higher in hot water curried RPC compare to normal water curried sample.
- Normal water curried sample give very low OPI value and which is near to 9.167 and it is very poor in oxygen permeability.
- Hot water curried sample with 1.0, 1.5, 2.0, 2.5, and 3.0% fiber having OPI value get between 8.99 to 9.25.which indicating poor oxygen permeability.
- However the above OPI of RPC is indicating poor permeability is due to the hardness of the rubber gasket is high.
- Reactive Powder Concrete was found to have poor permeability. OPI values for RPC similar, due to a significant amount of trapped lightweight material within the sample layer.
- The OPI value was also found to depend on the amount of stratification.
- The low OPI values indicate a 20mm cover depth in the testing specimen insufficient but a 30-40mm cover depth being adequate.
- The RPC is classified as a concrete with good to excellent absorption resistance but relatively porous, where the structural layer has high porosity due to trapped lightweight material.

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