COMPARATIVE ANALYSIS OF THE PERMEABILITY EVALUATED IN THE SIMPLE CONCRETE AND CONCRETE WITH ADDITION OF MICROSilica

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ABSTRACT

During the design for concrete durability; especially in situations where concrete is exposed to moisture it is important to consider the permeability parameter (k); which it can be improved by using additions, including microsilica (MS). The purpose of this research is to quantify the effect produced by small amounts of MS [5-10%] in the concrete permeability; the designed mixtures correspond to w/c rates from 0.40 to 0.60 and test ages 28, 56 and 100 days. The method used to determine the permeability parameter "k" was the hydrostatic pressure on one side of the specimen to determine the volume of water passing through or penetrates the material due to the pressure difference between its faces (similar to Darcy's experiment). The results show significant reductions in "k" due to the MS.

Keywords: microsilica, permeability, addition, durability, water pressure.

INTRODUCTION

The design of the concrete is commonly specified as a function of structural strength and stability, related to the compressive strength. It is now known that this is not sufficient to guarantee the concrete durability, therefore, specifications and durability recommendations must be established. The concrete durability is related to its ability to resist the action of weather, chemicals, abrasives or agents that generate deterioration process (American Concrete Institute, 2010). The penetrability of concrete is based on 3 mechanisms: permeability, capillary suction and ion migration (BERSZAKIEWICZ, 2008).

In the present research the permeability mechanism is analyzed for which the cylindrical specimens of concrete will be submitted to a constant hydrostatic pressure of 0.5MPa and uniform flow; Applying a water pressure directly on the concrete in order to calculate the permeability parameter "k", establishing comparisons, differences and improvements in obtaining the results of these tests with simple concrete and with addition of microsilica (5% and 10%). Permeability parameters that are taken as reference are those indicated in the standards of the ACI 318, UNE EN 12390 and NTC 4483.

THEORETICAL FRAMEWORK

Microsilica

Microsilica (MS), is widely used to produce high strength concrete, due to its puzzolanic reactivity. As reported by many authors, supplementary cementitious materials such as MS
have a beneficial influence on the durability of reinforced concrete. (ACI COMMITTEE 234, 2015)

The influence of microsilica on permeability in concrete has been studied from different perspectives such as transport properties (YÉPEZ, 2012) and chloride resistance (Fidjestol, 1997), its influence together with air-entraining agents (Pangil Choi, 2016) and its impact on the durability (MM Hossain, 2016), all validate the benefits of microsilica in concrete and mortar.

**Permeability analysis methods**

In Peru the most widely used method is the rapid permeability test of chlorides (based on electrical properties), which is normalized according to ASTM C1202, this test measures the exchange of chloride ions through the concrete.

The Spanish norm UNE EN 12390 describes the process to measure the permeability as a function of the amount of water entering the concrete by applying water pressure of 500 ± 50 kPa for three days to break the samples longitudinally according to ASTM C496C / C496M and measure the depth of penetration, which is the result reported.

In Latin America other standard such as the Chilean NCh 2262 are observed in which different pressures are applied, increasing in time, 0.1 MPa for 48 hours, then 0.3 MPa for 24 hours and finally 0.7 MPa for another 24 hours, with a tolerance range of 10% and finally measure the depth of penetration similar to the Spanish standard mentioned above.

Another case is Colombian standard NTC 4483 where the water pressure is applied at 0.5 ± 0.05 MPa for 4 days and depending on what happens during the test is that it considers two cases, when the water crosses the sample completely, it is measured the flow of water through the concrete; and the second case when the water only penetrates to a certain depth, where the average penetration depth is measured.

**Method of measurement by pressure method according to NTC 4483**

In order to determine the permeability parameter (K), cylindrical specimens of at least 15 cm diameter by 15 cm with a curing time of more than 28 days are required to ensure that cement hydration has been completed.

Then, the upper and lower faces wear out to avoid taking erroneous data, as they have different properties than the inside of the specimen.

The samples are dried in an oven, then the side surface of each of the samples is waterproofed by the use of a waterproofing paint.

They are then placed in the test equipment, applying a water pressure of 0.5 MPa, leaving the test pieces at this pressure for 4 days until one of the two options occur.

**Case 1: If the water passes through the sample, a flow of water is measured**

In this first case, the water will completely pass through the specimen, ie the specimen will be saturated and a flow of water will be felt on the opposite side to which the pressure is applied.

Once steady flow is established, the volume of water that pass through the specimen at a given time, either by making measurements of water level in the measuring cylinder or
measuring the flow in a vessel against time it will be determined. The permeability coefficient can be calculated from the following equation.

\[ K = \frac{\rho g L Q}{P A} \]  

(1)

Where:

- \( K \): Permeability parameter (m/s)
- \( \rho \): Water density (kg/m\(^3\))
- \( g \): Gravity acceleration (m/s\(^2\))
- \( L \): Specimen length (m)
- \( Q \): Water flow (m\(^3\)/s)
- \( P \): Water pressure (N/m\(^2\))
- \( A \): Cross-sectional area of the specimen (m\(^2\))

**Case 2: If the water does not pass through the sample, the depth of water penetration is measured.**

After 2 days without constant flow, the specimen is immediately sectioned perpendicular to the face on which the water pressure was applied by the indirect tensile test (ASTM C496), and the average depth of penetration.

Once the average depth of penetration has been determined, it is possible to deduce the permeability coefficient by means of the equation:

\[ K = \frac{D^2 v}{2T h} \]  

(2)

Where:

- \( K \): Permeability parameter (m/s)
- \( D \): Depth of penetration (m)
- \( v \): Porosity (determined by ASTM C642)
- \( T \): Time necessary to penetrate the D depth (s)
- \( h \): Water pressure load (m).

In this investigation we will measure the permeability using the standard NTC 4483: 1998 and thus determine the values of \( k \).

**RESULTS AND CONCLUSIONS**

The results of compressive strength and permeability both in terms of the parameter "k" as the penetration depth are shown in Table 1 and Figures 1, 2 and 3.
### Table 1 - Compressive Strength and Permeability tests results

<table>
<thead>
<tr>
<th>w/c ratio</th>
<th>0.4</th>
<th>0.45</th>
<th>0.5</th>
<th>0.55</th>
<th>0.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (days)</td>
<td>28</td>
<td>56</td>
<td>100</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td>Simple</td>
<td>37.4</td>
<td>10.1</td>
<td>2.83</td>
<td>50.5</td>
<td>23.9</td>
</tr>
<tr>
<td>5% MS</td>
<td>3.09</td>
<td>2.71</td>
<td>1.72</td>
<td>4.31</td>
<td>4.22</td>
</tr>
<tr>
<td>10% MS</td>
<td>1.06</td>
<td>0.95</td>
<td>0.25</td>
<td>1.58</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**Permeability Parameter k (x10^{-13} m/s)**

<table>
<thead>
<tr>
<th>Average Penetration Depth (mm)</th>
<th>Simple</th>
<th>5% MS</th>
<th>10% MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>35.3</td>
<td>12.7</td>
<td>7.7</td>
</tr>
<tr>
<td>56</td>
<td>21.0</td>
<td>11.9</td>
<td>7.3</td>
</tr>
<tr>
<td>100</td>
<td>41.5</td>
<td>9.52</td>
<td>3.75</td>
</tr>
</tbody>
</table>

**Average compressive strength at 28 days (kg/cm2)**

<table>
<thead>
<tr>
<th>Simple</th>
<th>475</th>
<th>453</th>
<th>426</th>
<th>398</th>
<th>330</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% MS</td>
<td>642.5</td>
<td>638.5</td>
<td>545.5</td>
<td>498</td>
<td>436</td>
</tr>
<tr>
<td>10% MS</td>
<td>730</td>
<td>692</td>
<td>638.5</td>
<td>517.5</td>
<td>511</td>
</tr>
</tbody>
</table>

Fig. 1 - Permeability Parameter k versus Age
Fig. 2 - Average Penetration Depth versus Age

Fig. 3 - Average compressive strength at 28 days versus W/c ratio
From these results it is observed that:

1. In all cases of permeability parameter at 28 days age, with additions of microsilica obtained values of permeability parameter in the range of $0.25 \times 10^{-13}$ to $7.50 \times 10^{-13}$, according to NTC 4483 these values indicate as low permeability classification.

2. At the age of 28 days in all designs with additions of microsilica, the penetration depth were less than 16 mm, according to NTC 4483 these values indicate as low permeability classification.

3. At the age of 56 days, in the mix designs with additions of microsilica identified as MS10%-0.60 and MS10%-0.55; It is observed that the values of $k$, are very similar so that to achieve a $k$ of $3 \times 10^{-13}$; the optimal mix is with w/c rate = 0.60 with 10% MS.

4. At the age of 56 days, the mix designs MS5% -0.60, MS5% -0.55 and MS5% -0.50 obtained very approximate $k$ values. From which it can be concluded that the mixture identified as MS5% -0.60 with optimal costs.

5. It is observed that at 56 days, the mixtures MS5% -0.6, MS5% -0.55, MS5% -0.5, MS5% -0.45 and MS5% -0.4 tend to the depth of penetration value equal to 13 mm; The mixtures of MS10% -0.6 and MS10% 0.55, tend to 10 mm and mixtures MS10% -0.5, MS10% -0.45 and MS10% -0.4 tend to 8 mm.

6. The lower permeability at 100 days was obtained with MS10%-0.40 design with the permeability parameter $k = 2.52 \times 10^{-14}$ and penetration depth equal to 3.75 mm, far exceeding what established by the NTC 4483 for a low permeability concrete.

7. On the average compressive strength at 28 days age it is verified once again the benefits of the addition of microsilica with respect to the simple concrete.

**RECOMMENDATIONS**

1. Continue with permeability measurements with other additions such as: limestone filler, meta kaolin, pozzolans and others since in the present investigation showed that the additions can improve the permeability.

2. Analyze the elastic behavior of concrete with additions of microsilica.

3. Make measurements of porosity over time in concrete improved with additions.

4. Perform measurements of capillarity over time in concrete improved with additions.

5. Study the durability of waterproof concrete with additions to aggressive media such as SO4, Cl-, Organic material, weathering, carbonation and others.

6. Using data mining (neural networks), the permeability parameter and depth of penetration of a concrete mix with microsilica additions can be predicted.
ACKNOWLEDGMENTS

The authors thank the vice-President of Research at UNI, the Laboratory of Materials Testing (LEM) of the National University of Engineering (UNI).

REFERENCES


