STUDY OF THE BOND STRENGTH BETWEEN PORTLAND CEMENT CONCRETE AND POROUS CONCRETE USED IN AIRPORT PAVEMENTS

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ABSTRACT

This paper presents a research on the bond strength between the underlying layer of Portland cement concrete (PCC) and the overlay of porous concrete for composite pavements, with special concern to concrete porous overlay for concrete pavement surfaces. Bond interface for such materials is taken as the key, once this condition allows significant reduction of bending stresses on the concrete slab, and the early loss of adherence would drastically commit the pavement performance. In order to clarify the behavior of bond interface under shear stresses, a laboratorial research was carried out using a Brazilian static strength shear test and the results are compared with PCC and asphalt concrete.

KEY WORDS

Porous concrete, composite pavements, bond strength, static strength shear test.
1. INTRODUCTION

Porous concrete has been used in pavements since 1990. It has been referred to as Portland cement pervious pavement or no-fine concrete, which is an open-graded material consisting of Portland cement, coarse aggregate and water. This is a concrete mix with a high void content, and it is, thus, a skeleton of uniform aggregate size and a minimum of fines. Porous pavement, effectively, reduces road spray and hydroplaning, and 15 – 25% interconnected porosity has been recommended.

The high permeability of this pavement is provided by the absence of fine aggregate and the high voids in the concrete (e.g. 20% by volume of concrete). A higher void content associated with crushed stone facilitates the formation of a good macrotexture and consequently good frictional. The technology improves road safety due to rapid drainage of rainwater (1).

Merighi et al. (2) recommend this material for use in low-traffic pavement conditions, parking areas and urban areas, but also as a wearing course in the upper concrete layer of airport runway pavements. It is recommended for environmental considerations because it traps rainwater and recharges the soil.

Germany, Netherlands and Spain have developed an investigation project - Brite-Euram BE 3415, called “Optimization of the superficial characteristics in Concrete pavement” The laboratories tests and structural analyses have been coordinated by the Spanish Cement Institute and their applications – IECA, the Materials Institute and Environmental Investigation (Netherlands) - O INTRON, The Polythecnic University of Catalunha and the Investigation Institute of Germany Cement Industry - VDZ (3).

Hoerner et al. (4) state that the initial experience in Belgium with this surface type showed poor durability in freezing weather; however, the durability of these mixtures has been improved with the addition of polymers and the use of higher cement content.

Onstenk et al. (5) give a list of the desirable properties: noise reduction, acceptable strength and stiffness, adequate surface properties with respect to traffic safety – skid resistance, evenness, sufficient service life - bonding to underlying dense concrete, costs comparable to those of conventional pavements.

The Georgia Stormwater Management Manual (6) defines a porous concrete layer as an open-graded concrete mixture usually ranging from 50 to 100 mm in thickness, depending on the bearing strength and pavement design requirements. They recommended a coarse aggregate of 9,5 mm maximum size to provide a smooth riding surface and to enhance handling and placement.

Merighi et al. (2) present in Figure 1 a schematic representation, which shows a high-porosity concrete system.
In terms of surface drainage, the authors show in Figure 2 different behaviour under water conditions between normal concrete and porous concrete. Percolation rates of 100 to 750 litres are usual. In other words, it traps rainwater and recharges ground water, reducing storm water run-off.

The technology of porous concrete has been utilized in low-traffic areas such as emergency vehicle and fire access lanes, golf cart and pedestrian paths, overflow parking areas, parking places in parking lots, pedestrian walkways, porous base layer for heavy duty use, recreation trails and residential street parking lanes (6).

The Georgia manual (6) states that the use of pervious concrete is limited because of high maintenance requirements, a traditional high failure rate and short life span. Special attention to design and construction is needed; it should not be used in areas of soils with low permeability, wellhead protection zones or recharge areas of water supply aquifers, and there are restrictions on use by heavy vehicles. It is intended for low-volume automobile traffic areas or for overflow parking applications.

This material is recommended as a wearing course in the upper concrete layer of airport runway pavements. Because of the thickness of this layer is in order of 6 to 10 cm, the bond interface for such materials is taken as the key once this condition allows significant reduction of bending stresses on the concrete slab, and the early loss of adherence would drastically commit the pavement performance (7, 8).
This paper presents a research of the behavior of bond interface under shear stress, in which a laboratorial research was carried out using a Brazilian static strength shear test.

2. TESTS TO DETERMINE THE SHEAR STRENGTH

Some of the main tests used to determine the shear strength (7, 9) are:
- pull-off test method;
- slant shear test;
- Grzybowska test;
- impacto-echo method;
- Wedge Splitting Test;
- pure tension;
- Iowa 406 – (test collar);
- Ancona Shear Testing;

In Figure 3 it is presented some limitations for the use of these tests (7, 9). Considering these difficulties, Fortes (9) proposes a simple test that was used in this research, called Brazilian shear testing.

3. EXPERIMENTAL PROGRAM

This paper reports an ongoing research at Mackenzie Presbyterian University to investigate the friction course in airport runway pavements.

The aim of the present research is to study the phenomenon of adherence between the underlying layer of Portland cement concrete and the overlay of porous concrete.

Data are presented on shear, compressive and flexural strengths. Permeability values are analyzed regarding aspects contributing to the development of new materials that could reduce the risk of hydroplaning.

3.1 Materials

Crushed granite was used from a local quarry, with maximum aggregate sizes of 12.5 mm for coarse aggregate and 9.5 mm for small crushed aggregate. The Los Angeles abrasion was 25.1%. River sand with a fineness modulus of 2.08 was used for the four mixes.

In this research it was used the mix A used by Merighi et al. (2), which had the value of compressive strength of 28 MPa, and porosity and permeability that was comparable with that found in OGFC layers. The flexural value was not high, but these two mixtures have the potential for increased resistance because the cement content was low, about 2.22 kN/m3.

3.2 Specimen Manufacturing

With the purpose to study the bond strength between Portland cement concrete and porous concrete, a test plan was developed considering two proceedings: overlaying a plaque of Portland cement concrete of 350 x 350 x 70 mm dimensions with porous concrete (see Figure 4 (a)), being applied in the interface two kinds of textural superficial treatment: with and
without brooming, as shown in Figure 4 (b) and molded 100 x 200 mm concrete cylinder as shown in Figure 5(a).
The cylindrical specimens from representative samples of fresh concrete followed the standard requirements for making, curing, protecting and transporting concrete test specimens. These specimens were cured in Moist Room, kept in a relative humidity of 80 percent and an average temperature of 20ºC, as recommended by NBR 5738/2003 (17).

THE PULL-OFF TEST method measures the adhesion between two layers applying a tensile force on the pavement surface. This test is appropriate to verify the adhesion under tensile stresses (10).

THE SLANT SHEAR TEST measures the shear resistance in the presence of a normal force. (11)

GRZYBOWSKA TEST was developed for asphalt concrete samples with geotextile interlayer. The prismatic specimens with 60 to 80 mm of length and submitted to the shear stresses (12)

IMPACTO-ECHO METHOD is a non-destructive test and measures the resistance of wave propagation. It detects areas where interfaces are unbounded. Results are not affected for the variations in bond strength. (13)

WEDGE SPLITTING TEST measures the shear resistance in presence of a normal force. (14)

PURE TENSION measures the adhesion between layers applying tensile force. The difficult is to keep the axial tensile. (15)

TEST METHOD IOWA 406 measures the direct shear strength using a collar mold. The sample is cored and put in this mold. So, it is applied tensile effort. (16)

ANCONA SHEAR TESTING was developed to measure the interface stress strain characteristics of two layer systems (10).

Figure 3: Some usual shear testing (7, 8):
The specimens were prepared as shown in Figure 5 (a) and (b). The prismatic specimen was obtained cutting the slab and bonding with epoxy resin as shown in Figure 5 (b).

3.3 Study of the bond between Portland cement concrete and porous concrete

The test was done as recommended by Fortes et al. (7, 9). Figure 6 (a) shows the cylindrical specimen and (b), the schematic test.

![Figure 6 - (a) cylindrical specimen (b) schematic shear test using cylindrical specimen](image)
The same results can be obtained capping the specimens as presented by Fortes (7, 9). The schematic specimen capping is shown in Figure 7.

Figure 7: (a) schematic specimen capping of prismatic specimen (b) schematic specimen capping of cylindrical specimen

Figure 8 (a) shows the cylindrical specimen set in the test machine and Figure 8 (b), the prismatic specimen.

Figure 8 - Static strength shear test using: (a) cylindrical specimen (b) specimen cut from the plaque

Figure 9 shows the rupture of cylindrical specimen.
4. EXPERIMENTAL RESULTS

The average results of the bond strength between the superficial layer and the concrete sub-layer are presented in Table 1.

Table 1 - Results of compressive, flexural, shear strength and permeability properties

<table>
<thead>
<tr>
<th>Compressive strengths (MPa) – 28 days</th>
<th>Permeability k (cm/s)</th>
<th>Flexural Strength (MPa)</th>
<th>Shear Strength in the interface (MPa)</th>
<th>Superficial treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.3</td>
<td>4.3 x 10^-3</td>
<td>2.2</td>
<td>6.1</td>
<td>brooming</td>
</tr>
<tr>
<td>4.9</td>
<td></td>
<td></td>
<td>4.9</td>
<td>without brooming</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations obtained from the present research are:

1) Porous concrete material can be recommended for the use in low-traffic pavement conditions, parking areas and urban areas, but also as a wearing course in the upper concrete layer of highways or airport runway pavements. It is recommended for environmental considerations because it traps rainwater and recharges the soil.

2) The static strength shear without brooming treatment was about 20% lower when compared to the one with brooming treatment. The strength shear in case of brooming surface was only about 40% compared compressive strength.

3) The result of the shear strength presented by Fortes (7) in case of asphalt concrete-Portland cement concrete interface was 1,637 MPa. The result obtained for the interface of porous concrete-Portland cement concrete was about three times higher.

The authors intend to continue their research by doing more tests related to other gradations and the bond between the Portland cement concrete slab and a thin porous concrete overlay.
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