Introduction

1. Introduction

2. Materials

2.1. Materials

Concrete, a limited substitute combined with a high risk of hazard and failure, is a crucial material in the construction of the Swiss network of highways. Despite its durability, concrete is subject to stress, which can lead to damage and failure. This paper aims to investigate the effectiveness of the non-destructive testing of repair mortars on the structural integrity of concrete structures. The study focuses on the development of new repair mortars with enhanced properties to improve the durability and strength of concrete structures. The non-destructive testing methods employed in this research include X-ray Fluorescence (XRF), Ultrasonic Pulse Velocity (UPV), and Magnetic Particle Testing (MPT) to evaluate the performance of the repair mortars. The results indicate that the new repair mortars significantly improve the structural integrity of concrete, making them a viable solution for repairing damaged concrete structures.
2.2 Testing methods

2.2.1 Compressive strength and ultrasonic pulse velocity of 7 and 28 days

The compressive strength at the age of 28 days was determined by the standard method of testing according to the American Society for Testing and Materials (ASTM C 39). The ultrasonic pulse velocity was measured using an ultrasonic testing apparatus according to the American Society for Testing and Materials (ASTM C 597). The results were compared with a control mixture of 1:2:4 cement:sand:aggregate in accordance with the American Society for Testing and Materials (ASTM C 597). The compressive strength was determined by measuring the maximum load that could be applied to the specimens before failure. The ultrasonic pulse velocity was determined by measuring the time it took for an ultrasonic wave to travel from one end of the specimen to the other.

Table 1: Composition of the Mixtures

| Water/cement | 0.45  | 0.40  | 0.35  | 0.30  | Total
|-------------|------|------|------|------|------
| Cement      | 300  | 320  | 340  | 360  | 1200 |
| Sand         | 550  | 550  | 550  | 550  | 2200 |
| Aggregate    | 650  | 650  | 650  | 650  | 2600 |
| Water        | 300  | 300  | 300  | 300  | 1200 |

Note: The values are in kg/m³.
The following modeling has been realized with the help of Dr. Peter

2.4 Numerical simulation

material is provided by a layer of paraffine gel.

Figure 1: Principle schemes of measurements: direct mode (left), indirect mode (right). The acoustic coupling between the transducers and the

cross-sectional area of the sample for the acoustic pulse

T : Measuring time

F : Resonant frequency

f : Resonant frequency

The velocity of sound is used in this testing. Though the direct mode is used for the experiments on consolidated samples, whereas the

direct waves are used for this study, shown on Figure 1. The

slow waves

\[ V_s = \frac{d (1 - 2V)}{\sqrt{1 - V^2}} \]

The following equations:

1. The propagation of sonic waves in a material assumed to be homogeneous and

2. Analytical solution to the velocity of sound in homogeneous and

Isotropic material

Table 2: W/C ratios used by the masses during the manual application of the

material

<table>
<thead>
<tr>
<th>Level No.</th>
<th>Mass A</th>
<th>Mass B</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.95</td>
<td>0.07</td>
</tr>
<tr>
<td>2</td>
<td>0.96</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>0.95</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Note: The velocity of these waves depends on the density and elastic constants of

By the indirect and direct mode:

V : Velocity of sound determined. When the velocity of sound does not depend on the material constant in the

slow waves

\[ V_s = \frac{d (1 - 2V)}{\sqrt{1 - V^2}} \]

Regarding the following equations, the scattering of the sound impulses by

The rearrangement of surface waves

\[ n = \frac{\sqrt{3}}{\sqrt{1 + 3V}} \]

\[ V_r = \frac{d (1 - 2V)}{\sqrt{1 - V^2}} \]

The following equations:

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3.1. Mechanical testing

Results

Equilibrium, we have assumed plane strain conditions for all computations, which yield:

\[
\begin{align*}
\text{Eq. 1} & \quad 0 = E_1 = E_2 = E_3 = 0.33 \\
\text{Eq. 2} & \quad 0 = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \\
\text{Eq. 3} & \quad 0 = \frac{\partial^2 u}{\partial x \partial y}
\end{align*}
\]
Table 3: Adhesive strength of type 1 specimens

<table>
<thead>
<tr>
<th>M/C</th>
<th>0.045</th>
<th>0.065</th>
<th>0.085</th>
<th>0.105</th>
<th>0.125</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>0.9</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>28 days</td>
<td>112 days</td>
<td>180 days</td>
<td>254 days</td>
<td>330 days</td>
</tr>
</tbody>
</table>

Tensile strength (MPa)

Figure 4: Creep of the mortar

Equation 15

\[ f = c + \frac{q}{r} \]

where:
- \( f \) is the shrinkage
- \( r \) is the radius of the mortar
- \( q \) is the load
- \( c \) is a constant

The results of the shrinkage tests are given in Figure 3. The values obtained for the modulus of elasticity with the following equation:

\[ E = 1.25 \times 10^5 \]

The British Standard B581 1972 permits to relate stress and strain to either static and dynamic load. Strains will be lower because of the WC that can be higher and the curing.
By assuming an error of 1.5% in the measurement of the velocity, the results of the experiments are compared to the theoretical predictions. The experimental data shown in this figure is for normalized Young's modulus and Poisson's ratio.

The experimental data indicates a good agreement between the theoretical and experimental results. The error bars represent the expected range of variation due to measurement uncertainties.

**Figure 6:** Compressive strength versus velocity of sound for normalized Young's modulus.

**Figure 7:** Velocity of sound versus W/C ratio determined on normalized prisms.
For a multilayered concrete:

- Water vapor on the application plane can only condense if the vapor pressure of the water exceeds the vapor pressure of the concrete.
- The water content of a multilayer system can affect the concrete's performance due to the presence of cracks.
- To prevent condensation, the use of a crack-closing agent or a crack-sealing material is recommended.
- Figure 1: Possibility of measurements with a thermographic device for determination of the distance between transducers in concrete.

**Figure 8:** Compressive strength versus velocity of sound for normalized conditions.

- The compressive strength is inversely proportional to the velocity of sound.
- The material's properties, such as density and porosity, significantly affect the compressive strength.
- The curve shows the relationship between the compressive strength and the velocity of sound under controlled conditions.

**Figure 9:** Travel time of sound in concrete.

- The travel time of sound is directly proportional to the distance between the transducers.
- The velocity of sound in concrete depends on factors such as the concrete's composition and humidity.
- The travel time of sound can be used to estimate the distance between transducers in concrete.
Figure 1: Variation of the stress $\sigma_{xx}$ in plane strain conditions at various time points.

- Time (hours) 0 12 24 36 48 60 72
- Stress ($\sigma_{xx}$) 0 0.5 1 1.5 2 2.5 3

Figure 2: Thermal history of the well

- Time (hours) 0 12 24 36 48 60 72
- Temperature ($^\circ$C) 10 11 12 13 14 15 16

The thermal history is due to thermal loads on the materials. The thermal loads at the surface (convection conditions), whereas the damping of the thermal variations are found at the surface (convection conditions), whereas the damping of the thermal variations is shown in Figure 3.

Numerical simulation

The stress state of the X-Y plane of the well after 72 hours of cutting is shown in Figure 1. The stress at the Y plane is shown in Figure 2. The state of the stress in the X-Y plane of the well after 72 hours of cutting is shown in Figure 3.
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