Study of the strength properties of modified concrete in tension

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Abstract. The resistance of concrete to axial tension is much less than the resistance to compression and is largely determined by the adhesion of its components. The low tensile strength of ordinary concrete is explained by the heterogeneity of its structure and the discontinuity of concrete, which contributes to the development of stress concentration, especially under the action of tensile forces. To increase the tensile strength of concrete, it is necessary to eliminate, first of all, the heterogeneity of the structure of concrete - one of the main reasons for the large dispersion of the results of mechanical tests of this material, which affects the experimental determination of compressive strength. A significant difference between the compressive strength for ordinary concrete indicates a rather large spread of such values. This scatter is explained by the different influence of factors on tension and compression. For example, for ordinary concretes, it was found that with an increase in $W/C$, the tensile strength decreases, but to a lesser extent than the compressive strength. With an increase in the grade of concrete, the tensile strength increases. High-strength concretes, as a rule, prepared on concrete mixes with low $W/C$ and on clean conditioned aggregates in the form of crushed stone and sand, have an increased density, therefore, they have less variation in strength readings both in compression and at stretching [1-4].

1 Introduction

To determine the value of the temporary tensile strength $R_{st}$ at one time, Fere proposed dependence in the form:

$$R_{st} = 0.50 \cdot R^{2/3}$$

At present, this dependence also applies to concrete of grade 600 and more.

Under the action of vibro-impact pressing, the concrete is compacted, which is characterized by a decrease in the thickness (height) of the sample. In all experimental observations, small discrepancies in the relative strain were noted at different heights of the samples, i.e. the dimensions of the samples were taken as 80 x 80, 100 x 100, 150 x 150,
and the concrete composition was 1 : 1.1 : 2.84 at (\(W/C\))_{beginning} = 0.35.

Thus, during vibro-impact pressing of a concrete mixture, preliminary vibro-impact compaction creates favorable conditions for uniform deformation of the mixture. In the process of vibro-impact compaction of the concrete mixture, the aggregate grains begin to move, meeting, repel each other and from the mold walls. As a result, a layer of cement paste appears between them, increasing the homogeneity of the cementing matrix, which contributes to a more compact arrangement of aggregate grains in the concrete mixture. The foregoing is confirmed by the fact that on the surface of samples prepared by vibro-impact pressing without preliminary vibro-impact compaction, individual grains of coarse aggregate were observed that were not covered with cement mortar [6-11].

For samples made by vibro-impact pressing, after preliminary vibration of the mixture, the outer surface consisted mainly of cement stone with a thickness of 0.5 ... 1.0 mm.

2 Methods

As a result of the analysis of modern technologies, it has been established that physical modification is possible by removing excess water added to the concrete mixture to give it the necessary fluidity and workability.

In the process of removing excess water and entrained air, the cement particles will begin to approach each other, which, in turn, will lead to the convergence of grains of coarse and fine aggregates. The normal pressure that is transferred to the water and causes its removal will contribute to the approach of the particles until the external pressure is completely perceived by the dispersed phase.

The removal of free water during the compaction process maximizes the use of the potential properties of cement to increase the density, water resistance and strength of concrete. Currently, in the technology of complex elements, there are several methods for dehydrating a concrete mixture: centrifugation, pressing, vacuuming, vibro-compression, etc. One of the most effective methods should be considered a vibro-peristaltic pressing method, since this can create the necessary conditions for maximum dehydration of a concrete mixture, and concrete.

3 Results and Discussion

The mode of vibrocompression of the concrete mix with dehydration (Table 1) provides the possibility of reducing the water-cement ratio from 0.31...0.40 to 0.263...0.290, i.e. by 14...29.5% of the initial A/C. As a result, the compressive strength of concrete at the age of 28 days increased to 110.7 MPa, the tensile strength reached 16 MPa, and the water resistance increased to 3 MPa. The values of \(R_c\) and \(R_{st}\) for HCMC and conventional concrete are shown in figure 1. At the same time, the value of \(Rp\) for ordinary concretes was taken according to the experimental data of O.Y.Berg [6]. It is characteristic that the area of hypercompacted concrete lies above the area of ordinary and even high-strength concretes [19, 20]. A particularly significant difference in the values of \(R_{st}\) was observed in extra-strong hyper-compacted concretes.
<table>
<thead>
<tr>
<th>№</th>
<th>Initial W/C</th>
<th>Cement (C)</th>
<th>Sand (S)</th>
<th>Gravel (G)</th>
<th>Water (W)</th>
<th>Vibro pressing mode</th>
<th>The amount of squeezed water, %</th>
<th>Residual W/C</th>
<th>Compressive strength, MPa, 28 days</th>
<th>Δ = $R_{C}^{EP}$/$R_{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.31</td>
<td>530</td>
<td>495</td>
<td>1272</td>
<td>165</td>
<td>14.0</td>
<td>0.268</td>
<td>101.3</td>
<td>46.7</td>
<td>2.17</td>
</tr>
<tr>
<td>2</td>
<td>0.33</td>
<td>490</td>
<td>506</td>
<td>1300</td>
<td>162</td>
<td>17.9</td>
<td>0.271</td>
<td>96.3</td>
<td>45</td>
<td>2.14</td>
</tr>
<tr>
<td>3</td>
<td>0.35</td>
<td>460</td>
<td>508</td>
<td>1308</td>
<td>161</td>
<td>21.7</td>
<td>0.278</td>
<td>90.5</td>
<td>42.1</td>
<td>2.15</td>
</tr>
<tr>
<td>4</td>
<td>0.37</td>
<td>430</td>
<td>512</td>
<td>1316</td>
<td>159</td>
<td>22.6</td>
<td>0.287</td>
<td>79.4</td>
<td>40.3</td>
<td>1.97</td>
</tr>
<tr>
<td>5</td>
<td>0.40</td>
<td>397</td>
<td>516</td>
<td>1326</td>
<td>159</td>
<td>27.3</td>
<td>0.290</td>
<td>67.1</td>
<td>34.6</td>
<td>1.94</td>
</tr>
</tbody>
</table>

Note: Above the line - test results of concrete samples, compacted; vibro-impact pressing, under the line - the same, compacted by vibration, where: $R_{st, v- i}$ - strength of vibro-impact-peristaltically pressed concrete; $R_{st, v-c}$ is the strength of vibro-compacted concrete.

A significant change in the strength of concrete in compression and tension ($R_{C}$ / $R_{st}$) is characterized by the fact that this ratio decreases with a decrease in ($W/C_{beg}$). It can be concluded that with a decrease in the initial $W/C$, the efficiency of hyperdensification increases [22–24]. The greatest hyper-compaction effect was observed at ($W/C_{beg}$) = 0.31, when the $R_{C}/R_{st}$ ratio decreased to 7...8. Therefore, the average tensile strength of hyper-compacted concrete was 109.7/6.9=15.9 MPa. Such tensile strength corresponds to the M150 grade of ordinary concrete in compression. This material is able to withstand...
significant tensile stresses. For example, it can be reliably used without reinforcement for non-pressure and low-pressure tubular elements. A production review of these provisions confirmed the validity and reliability of these provisions.

Fig. 1. The dependence of the strength of concrete in axial tension $R_{st}$ on its cylindrical strength $R_c$:

The ratio of the strength of concrete in tension and compression, given in table 2 are also reflected in the graph, figure 2.

An analysis of the experimental data for determining the tensile strength of hyper-compacted concrete leads to the conclusion that the use of the Fere formula is impossible. As follows from dependence (1), the coefficient 0.5 is a constant value. This may be true for vibro-compacted concrete. During hyper consolidation and modification of concrete, the coefficient in the Fere formula becomes variable and depends on the value of the compressive strength of concrete, Fig. 3. From experimental data it follows that when the strength of concrete changes from 70 to 110 MPa, the coefficient increases from 0.55 to 0.70. One can accept the linear dependence of $K_r$ on $K_b$. In this case, Fere's formula for hyper-compacted modified concrete takes the form:

$$R_{st} = K \cdot R_c^{1/2}R_c$$

(2)
Table 2. The ratio of the strength of concrete in tension and compression

<table>
<thead>
<tr>
<th>Strength characteristic of concrete, MPa, at the age of 28 days</th>
<th>Designation</th>
<th>$(W/C)<em>{beg}/(W/C)</em>{res.av}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.265</td>
</tr>
<tr>
<td>Vibrocompacted</td>
<td>$R_c$</td>
<td>46.3</td>
</tr>
<tr>
<td></td>
<td>$R_{st}$</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>$R_c/R_{st}$</td>
<td>9.1</td>
</tr>
<tr>
<td>Vibro-impact-pressed</td>
<td>$R_c$</td>
<td>109.7</td>
</tr>
<tr>
<td></td>
<td>$R_{st}$</td>
<td>15.9</td>
</tr>
<tr>
<td></td>
<td>$R_c/R_{st}$</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Fig. 2. The ratio of the strength of concrete in tension and compression: 1 - concrete, compacted by vibration; 2 - concrete compacted by vibro-impact pressing.

Fig. 3. The dependence of the stretching coefficient in the refined Fere formula for hyper-compacted modified concrete (HCMC)
It is more rational to bring this formula to the form:

$$R_{st} = \frac{k^2 R_c^3}{100}.$$  \hspace{1cm} (3)

As shown by the experiments, this dependence makes it possible to reliably predict the tensile strength of hyper compacted concrete. It should be noted that for HCMC with a strength above 90 MPa, the $R_c/R_{st}$ ratio decreases to 7...8. Consequently, high-intensity compaction and modification of concrete also leads to an increase in the homogeneity of the material, and, consequently, an additional increase in tensile strength.

4 Conclusions

1. The developed complex method of hyper-consolidation and modification of the concrete mixture makes it possible to increase the strength of experimental concrete by 2...2.2 times compared to the strength of vibro-compacted concrete with the same initial W/C value

2. The ratio between the strength of hyper-compacted concrete and $(W/C)_{res}$ is linear, however, the tangent of the slope of the dependence $R_c = (W/C)_{res}$ is 2 times greater than the analogous parameter of vibrocompacted concrete.

3. The functional dependence of the strength of hyper compacted concrete on its structural components, strength, elasticity and deformability of the corresponding cement stone and mortar part of concrete has been established, while the dependence of $R_c$ on $R_{st}$ and $K_{dis}$ is approximately linear.

4. Experiments have shown that hyper consolidation, together with the modification of the concrete mixture, has a greater effect on the tensile strength of concrete, while the ratio $R_c / R_{st}$ decreases to 7...8 compared to the same indicator of high-strength concrete, equal to 9 ...10. A refined dependence is proposed for determining $R_{st}$ by grade strength $R_c$ obtained from the Fere formula.

References


napryazheniy, 70, Moscow (1969)


