Study on Strength Characteristics of Vibro vacuumised Concrete Cylinders with Hollow Section

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Abstract – This article presents the results of a study on strength characteristics of concrete cylinders with hollow section. The obtained conversion of Klein formula allows determining the application range of concrete cylinders and predicting their strength properties. A pilot plant is presented for the manufacture of hollow concrete cylinders by vibrovacuumizing.

Index Terms: concrete cylinders with hollow section, vibrovacuumizing, strength characteristics.

I. INTRODUCTION

Concrete cylinders with hollow section of different purpose are characterized by the extensive application: in chemical and petrochemical industries for transporting highly corrosive and sterile environments; in construction; in urban public utility systems. Ensuring reliable operation of this type of structures throughout the entire lifetime is associated with maintaining their integrity under various load conditions, and depends on the accuracy of the methods of determining the strength taking into account manufacturing techniques.

As early as in the 30s of the previous century vacuum compaction of concrete mixes has been used successfully in the construction of buildings and structures of mass concrete [1], [2], [4], [5]. In practice, back at that time the advantages of vacuum compaction of concrete mixes in monolithic structures had already been convincingly proved. The main ones are the following:

- increase in labor productivity;
- reduction of the period of construction of buildings or individual structures;
- significant reduction in metal consumption (material consumption) by formwork;
- energy savings;
- reduction of specific consumption of cement;
- significant improvement in concrete quality.

However, in the 1950s because of the overuse of harsh and even very harsh mixes, vacuum compaction method has been undeservedly forgotten. But it was soon discovered that the use of harsh concrete mixes in the construction of monolithic structures is associated with a number of major shortcomings of the technological and technical nature [12]. Therefore, back in the 1960s it has been argued [1] that this method of compaction of concrete mixes shall be resumed and applied in the areas, where it is technically feasible and economically beneficial. Significant contribution to the solution of strength problems in vacuum treated concrete structures made researchers A.M. Asirian [1], V.P. Artemtsev [2], V.L. Epstein [3], O.A. Gershberg [4], [5], V.M. Malhotra [8], B.G. Skramtsev [10], N.A. Storozhuk [11]–[13], I.A. Sokolov [14], A.G. Vandolovskiy [15] and others. To date, the operating conditions of concrete processing units are studied taking into account vacuum effect optimization. The aim of this work is to study the strength characteristics of concrete cylinders with hollow section formed by the method of vibrovacuumizing.

II. MATERIALS AND METHODS

In industrial practice a result is known that the application of vibro-vacuum treatment of concrete mixes when forming precast products and erecting structures of monolithic concrete allows eliminating the problem of water...
consumption by concrete aggregates and, accordingly, considerably improving the quality of concrete (e.g., in terms of strength, frost resistance, etc.) [11], [12]. Simultaneous application of vibration action significantly increases the efficiency of concrete mix compaction [6], [7], [9]. On this basis, we proposed a new method for the manufacture of concrete cylinders with hollow section with the application of vibrovacuumizing technology.

This method allows the acquisition by concrete of positive properties: intense rise in strength during the initial period of hardening, reducing the time for thermal treatment of products, reduction in metal consumption by processing equipment, etc. The degree of concrete mix compaction depends on the frequency and amplitude of vibrator, as well as on the duration of vibration. For compacting concrete mixes vibration amplitude is within 0.3 mm – 0.7 mm at a frequency of about 3000 vibrations per minute.

For the vacuum treatment of laid concrete the stationary and mobile units are used, which consist of a vacuum pump and vacuum shield coated with filter medium.

III. STUDY ON THE STRENGTH CHARACTERISTICS OF CONCRETE CYLINDERS

As a result of laboratory research on the proposed laboratory setup (Fig. 1) using vibrovacuumizing method concrete cylinders with hollow section were produced (Fig. 2).

The results showed that the tensile strength of these concrete cylinders is by 40% higher than that of the cylinders produced by layer-axial compression and vibration.

To determine bearing capacity of the cylinders with hollow section the main loads (Fig. 3, Fig. 4) were identified and "three-point method" and Klein equation [2], [3], [5] were used, resulting in determining maximum failure load \( P \) per 1 running meter of the cylinder.
Normal circumferential stresses $\sigma_p$ were determined by the equation (1):

$$\sigma_p = \frac{1.1 \cdot P \cdot r_c}{c \cdot c^2}$$

where $P$ is reduced load;
$r_{cp}$ is average pipe radius;
$c$ is wall thickness;
$B$ is pipe length.

Given that equation (1) shows various geometrical parameters, which can not be used in the design of the cylinders and pipes, it is proposed to use in calculations the ratio $n = \frac{d}{c}$ that allows bringing the equation (1) to the transformed equation (2):
\[ \sigma_p = \frac{1.1 \cdot \rho \cdot \left( \frac{d + \frac{d}{n}}{n} \right)}{100.2 \frac{d^2}{n^2}} = 0.0055 \cdot \rho \cdot d \cdot \left( \frac{d + \frac{d}{n}}{n} \right) \cdot \frac{d^2}{n^2} = 0.0055 \rho \cdot \left( \frac{d^2 + nr^2}{n^2 d} \right) = 0.0055 \rho \cdot \frac{d^2 (1 + n)}{nd^2} = 0.0055 \rho \cdot \frac{n}{d} = 0.0055 \rho \frac{n(1+n)}{d} \]

Where \( A = 0.0055n \ (n+1) \)

Fig. 5. A coefficients for the design of concrete cylinders with hollow section

The research demonstrated the possibility of using A coefficients within a narrow range of the cylinders actually used \( n = 6\ldots9 \) (Fig. 5). Within this range for the external load (\( P \)):

\[ A = 0.0064 \ n^2 \]

Table I shows the comparative results of calculations by the equation (1) and proposed one (3). Calculated deviations do not exceed 2.4%.

<table>
<thead>
<tr>
<th>( n )</th>
<th>( A = 0.0055n \ (n + 1) )</th>
<th>( A = 0.007618 \ n^{1.9} )</th>
<th>( \Delta A )</th>
<th>( % )</th>
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<td>6</td>
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IV. CONCLUSIONS

Based on the studies carried out it was found, that high quality of compaction is achieved when using for forming concrete cylinders with hollow section a method of vibrovacuumizing. Conversion of known dependencies in order to determine normal circumferential stresses from external load allowed us to obtain new dependencies for the calculation of stresses in concrete cylinders with hollow section under the joint action of external (reduced) load. Using these equations allows determining the application range of concrete cylinders. These studies are relevant for construction products such as pipelines, columns, piles, etc. And the possibility of combining vacuum treatment with other process operations opens up the prospect for application of vacuum treatment of concrete mixes in the
construction of buildings or separate structures of mass concrete.

REFERENCES


AUTHOR BIOGRAPHY

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