Prescription and Technological Aspects of Manufacturing High-Quality Centrifuged Products and Structures from Heavy Concrete

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Abstract. The previous studies of centrifuged reinforced concrete structures, aimed at the supports of contact lighting networks, poles of power transmission lines, columns of single-stage buildings and overpasses, piles-shells were studied. A number of experimental studies were carried out in the Technology of binders, concretes and construction ceramics laboratory of Don State Technical University Academy of Construction and Architecture. An experimental laboratory unit-centrifuge TsSRL-1 with a DC motor with thyristor power units was developed and applied. It was noted that number of rotations is the most essential parameter to regulate the average density and, correspondingly, the wall thickness of the centrifuged product. It is confirmed that the final sealing of the walls by centrifugation happens when the maximum compressive pressure is applied on the walls complied with the rotation speed of the mold at the sealing number of the shape revolutions. The main parameters of centrifugation during this period are the sealing speed of the shape and the duration of centrifugation. The result of the experiments allowed finding the optimal ratio between sand and granite crushed stone, which ensures a minimum cement consumption for centrifuged concrete B40 and a minimum yield of cement to the slurry.

1. Introduction

The development trends in modern construction depend on the technological features of manufacturing reinforced-concrete products, which includes the use of centrifugation and vibrations. When researching and developing new building structures, one needs a systematic approach that could cover the design, the construction, and the manufacture of products.

The development of multi-storey construction aims at improving the shapes and structures of buildings, which is a result of better physico-mechanical properties of construction materials. Using high-strength steels and concretes enables the creation of lightweight thin-walled reinforced-concrete structures and is possible when there is an advanced technology of producing such elements in place provided a well-developed theory for computing their properties.
Earlier research of centrifuged reinforced-concrete structure was focused on the towers of lightning grids, the power-line tower supports, the columns of single-storey buildings and flyovers, as well as on pile shells.

2. Experimental program and research results
A number of studies was conducted at the laboratory of the Department for Technology of Binders, Concretes, and Ceramic Engineering of the Constructure and Architecture Academy, Don State Technical University.

The advantage of roller centrifuge is the possibility to produce large-diameter products and structures, use higher dosage when pouring the mix into a rotating mold, and the convenient discharge of sludge after centrifugation. Vibrations caused by the surface irregularities of rollers and bandages result in a higher-quality densing of the mixture.

For this research, the researchers developed and used an experimental centrifuge machine titled ЦСРЛ-1 that had a DC motor with thyristor power supplies. This enabled smooth speed switching by altering the motor shaft rotation speed. Figure 1 shows the schematic diagram of the ЦСРЛ-1 experimental centrifuge with a mold.

**Figure 1.** Schematic representation of the CSRL-1 centrifuge:

1 – drive sheave; 2 – driving track roller; 3 – driven track roller; 4 – bearing sleeve shaft retainer, with ball bearing; 5 – fixture element fastening the support to the bed (M12 bolt); 6 – mold; 7 – connection of two halves of the mold (M8 bolt)

The experiment helped specify the optimal parameters for the centrifugation of annular heavyweight-concrete products:
- densification time \( \tau = 3.5 \text{ min (approx.)} \);
- rotation speed \( n = 1000 \text{ rpm} \).

Note that the rotation speed was the most efficient parameter in terms of controlling the average density and hence the wall thickness of the centrifuged product.

Besides, greater average density had a positive effect on all the physico-mechanical properties of heavyweight centrifuged concrete.
Compositions were calculated for three cement consumption options: 500, 550, and 600 kg/m³; the concrete workability grade was Π1 (cone slump CS = 2 to 3 cm at the time of centrifugation).

The concrete mixture for control samples was made by the БЛ-10 laboratory forced-mixing machine. Figure 2 is a photograph of the sample.

Figure 2. Centrifuged concrete sample

The necessary duration of centrifugation was assumed to equal 20 minutes. After a three-hour curing period, samples were subjected to steam treatment in a 3+10+3-hour mode at an isothermal heating temperature of 80±2 °C.

Before testing, samples were cured for 27 days under normal conditions, after which samples of the required shape and size were cut. Figure 3 shows the test results.

Figure 3. Dependency of the strength of centrifugation concretes with different cement content on the residual water-cement ratio (WC)

As a result of these experiments, the researchers managed to find an optimal (see Figure 4) sand and granite gravel ratio $S/G = 0.3$ that minimized the consumption of cement for making B40 concrete ($C = 520$ kg/m³) as well as the content of cement in the sludge extracted as a result of 20-minute centrifugal densification. Table 1 shows the composition of the centrifuged concrete.
Table 1. Centrifuged concrete composition

| Composition | Consumption per 1 m³ of concrete, kg | Sludge density, g/cm³ | W/C initial | W/C final | Compressive strength, MPa |
|-------------|-------------------------------------|----------------------|-------------|-----------|--------------------------|
| Cement      | 520°                                 | 10±20 5±10 2.5±5     | 1.22        | 0.371     | 0.338 50 43 |
| Water       | 193 520°                              |                      |             |           |                          |
| Sand        | 396 405                               |                      |             |           |                          |
| Granite gravel, fractions mm | 2.5±5 7±10 |                      |             |           |                          |
| CNé1        | 778 796                               |                      |             |           |                          |
|            | 409 418                               |                      |             |           |                          |
|            | 132 135                               |                      |             |           |                          |

° The value above the line was recorded before, and the value below the line was recorded after, the centrifugation.

Figure 4. Optimal cement consumption for centrifuged B40 concrete at 28 days of age (heavyweight concrete)

3. Conclusion

The obtained B40 concrete composition is recommended for further research to improve the operating qualities of annular products and structures of heavyweight concrete.

Final densification of walls by centrifugation occurs when these walls are exposed to maximum pressing pressure as the mold rotates at its densing speed. The main centrifugation parameters in this timeframe are the densing speed of the mold as well as the duration of centrifugation.

The optimal pressure we assumed was the one at which the concrete porosity stabilized, with the porosity being defined as the surface-to-volume ratio; the optimal densification time assumed was the one at which the mass stabilized.

Traditional centrifugation techniques feature different mold rotation speeds at pouring and at distributing the concrete mix. During densification, the mold rotation speed is altered in a very wide range and greatly depends on the viscosity of the concrete mixture as well as on the pressing pressure. Using a laboratory machine to simulate the forming parameters for the centrifugation of annular products at maximum pressing pressure cm2 cm2 cm22 will help refine these data and study their effect on the variation of the structure of centrifuged concretes.

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