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The analysis of technological parameters of precast-monolithic system with permanent formwork walls

S A Serbin[1], P O Dedyukhin[2], N I Fomin[3]

[1]Department of civil engineering, Ural Federal University, 17 Mira Street, Yekaterinburg, 620002, Russia
[2]Department of civil engineering, Ural Federal University, 17 Mira Street, Yekaterinburg, 620002, Russia
[3]Department of civil engineering, Ural Federal University, 17 Mira Street, Yekaterinburg, 620002, Russia

E-mail: Andrey-sergey.serbin@yandex.ru

Abstract. This article presents a brief description of the research, which consists of determine the optimal parameters of the bay of concreting permanent formwork walls with a spatial reinforcing cage for the construction of precast-monolithic reinforced concrete structures in the construction of civil, public and industrial buildings. The results are presented in the form of graphs, by means of them it is possible according to the specified parameters of permanent formwork, such as the step of the spatial reinforcing cage, the thickness of the monolithic core and the total thickness of the formwork, to determine the recommended technological parameters of construction work, which will not only avoid the destruction of permanent formwork in the process of concrete work in the construction of precast-monolithic reinforced concrete structures in the construction of civil, public and industrial buildings, but also to maximize their manufacturability**.**

1. Introduction

Construction companies using precast-monolithic structures as wall elements have repeatedly faced the problem of destruction of the panels outer shell during concreting.

The aim of the research is to determine the optimal parameters of the bay of concreting permanent formwork walls with spatial reinforcing cage for the construction of precast-monolithic reinforced concrete structures in the construction of civil, public and industrial buildings and development of technological recommendations for the production of concrete works.

When we had studied native and foreign experience on this topic [6–10] it was determined that the calculation part of the research is to determine the maximum values of the concreting speed (m/h), at which the prefabricated elements of the permanent formwork of the walls will be able to accept technological loads from both the longitudinal forces and the bending moment without destruction. To do this, consider the section of the prefabricated part of the wall element of size bxb (size b varies depending on the types and sizes of the selected reinforcing cage [5]. Note that the calculated area is selected in such a way that there is no reinforcing bars (Fig. 1).

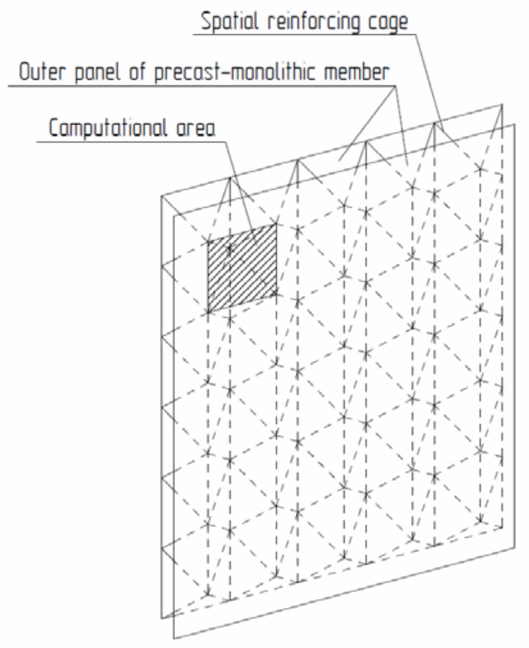

Figure 1. Computational model.

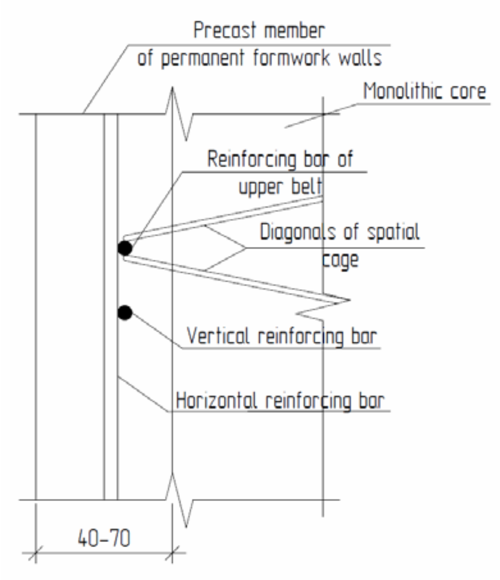

Figure 2. Cross-section of the precast member of permanent formwork with a monolithic core.

2. Calculation part

According to the loads (from the pressure of the concrete mixture and from the effects of wind) acting on the calculated area, we obtain two types of destructive effects:

1. The maximum values of the longitudinal force in the area of the cargo area $A_{ar} = b \cdot b$ (Fig. 1);

2. Bending moment in the aisle and on the bearer of the selected area.

To begin with, we started toanalyze the first condition: the value of the distributed load from external forces should be less than the holding force distributed over the cargo area and resulting from the welded connection of diagonals with the lower and upper belt and the length of the anchoring of the diagonals of the spatial frame into the body of the assembled part of the permanent wall formwork [7]:

$$R_{br} \le R_h, \quad (1)$$

where R_{br} – breaking pressure on the section of the cargo area $A_{c.a.} = H \cdot B$, kPa; H, B –step of reinforcing cage in the longitudinal and transverse directions; R_h – maximum holding pressure that can be sensed by the cargo area, kPa.

The breaking pressure is determined by the formula:

$$R_{br} = P_{c.m.} + P_w, \quad (2)$$

where $P_{c.m.}$ – maximum lateral pressure of concrete mixture, kPa; P_w –the wind pressure occurring at a height of 80 m (the height is conventionally accepted as the highest point of the element location), kPa.

The maximum lateral pressure of the concrete mixture is determined by the formula for calculating the lateral pressure of the concrete mixture when compacted by vibrators on the ADJ. T [1]:

$$P_{c.m.} = g \cdot (0,27 \cdot V + 0,78) \cdot K_1 \cdot K_2, \quad (3)$$

where g – volume weight of concrete mix, kg/m^3; V – concrete casting rate (rate of filling of the formwork height), m/h; K_1 – coefficient taking into account the influence of mobility (stiffness) of the concrete mixture; for the worst case, at OK more than 8 cm. K_2 – coefficient taking into account the influence of temperature of concrete mix; $K_2 = 1{,}15$ – for the lowest possible concreting temperature of 5-10°C.

Wind pressure is determined by the formula11.1 [2]:

$$P_w = w_m + w_p, \quad (4)$$

where w_m – average component of the main wind load, kPa; w_p – pulsation component of wind load, kPa.

Determination of the standard value of the average component of the main wind load:

$$w_m = w_0 \cdot k(z_e) \cdot c, \quad (5)$$

where w_0 –standard value of wind pressure, determined by the table. 10.1 [2], kPa; $k(z_e)$ – coefficient taking into account the change in wind pressure for height, determined by table. 11.2 [2], which is taken equal to 1.45 for 80 m; c – the aerodynamic coefficient is determined by ADJ. B.1.1 [2], which is taken equal to 1.8 m for territories of type B.

Determination of the pulsation component of the main wind load:

$$w_p = w_m \cdot \zeta(z_e) \cdot v, \quad (6)$$

where $\zeta(z_e)$ – the coefficient of wind pressure pulsation, taken according to table. 11.4 [2], numerically equal to 0.7 for a height of 80 m; v – the coefficient of spatial correlation of wind pressure pulsations, determined by table. 11.6 [2], which is taken equal to 0.73 for 80 m.

The holding pressure is determined by the formula:

$$R_h = \frac{F_h}{A_{ar}}, \quad (7)$$

where F_h – the total holding force, kN;

The total holding force is determined by the formula:

$$F_h = F_j + F_{an}, \quad (8)$$

where F_j – strength in shear of a welded joint, determined by tables A.1-A.3 [3], which is takenequal to 6 kN for the lower belt at a diagonal Ø 5 mm; F_{an} – the resistance of the adhesion reinforcing bar with concreteon the anchorage length

The adhesion resistance of the reinforcement with concrete on the anchorage length is determined by the formula:

$$F_{an} = R_{bond} \cdot u_s \cdot l_{an}, \tag{9}$$

where R_{bond} – the design resistance of reinforcing bar adhesion with concrete, taken uniformly distributed along the length of the anchorage, determined by the formula 10.2 [4], kN; u_s – the entire cross-section of anchorage reinforcing bar, m^2; l_{an} –anchorage length of reinforcing bar, m.

$$R_{bond} = \eta_1 \cdot \eta_2 \cdot R_{bt}, \tag{10}$$

where η_1 – coefficient, taking into account the influence of the type of surface reinforcing bar, taken equal to 2.5 for high-rolled reinforcement; η_2 – coefficient, takingintoaccountthe influence of diameter size of reinforcing bar, which is taken equal to 1,0 for $d \le 32$ mm; R_{bt} – the design resistance of concrete to axial stretching, as defined in the table. 6.8 [4], which is taken equal to 1.05 MPa for concrete class B25.

The essence of the second condition is that the bending moment arising from the action of the external load in the aisle or on the bearer was less than the limiting bending moment, which can be perceived by the cross section of the element of the precast member of the permanent wall formwork, p.7.1.12 [4]:

$$M \le M_{ult}, \tag{11}$$

where M – the bending moment from the external loads, kNm; M_{ult} –the ultimate bending moment, kNm.

The value of the limiting bending moment is determined by the formula 7.9 [4]:

$$M_{ult} = R_{bt} \cdot W, \tag{12}$$

where W – resistance moment of the element cross section theoutermost tensile fiber;

The moment of resistance of the cross section of the element for the outermost stretched fiber of rectangular elements is determined by the formula 7.10 [4]:

$$W = \frac{b \cdot h^2}{6}, \tag{13}$$

The bending moment of the external load is determined by the formula 14:

$$M = k_1 \cdot R_{br}, \tag{14}$$

where k_1 –coefficient taking into account the nature of the action of the bending moment (at bearer or in the aisle), determined in accordance with table 14.31 [5], which is taken equal to the aisle – 0,0179 in the bearer – 0,0417.

As a result of mathematical calculations using the presented formulas and values, taking into account the requirements for wall elements and the specification of reinforcing cages presented in [3], the following data were obtained, which are presented in Fig. 3, Fig. 4, Fig. 5, Fig. 6. The values are given for the concrete pump rated capacity of 164 m^3/h, with an increase in its performance requires recalculation.

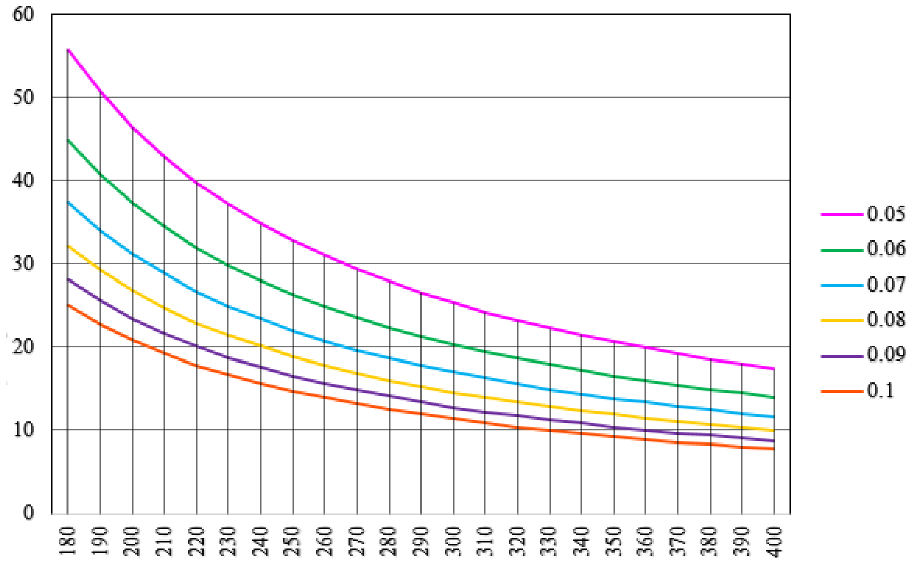

Figure 3. The dependence of the minimum total bay length on the thickness of the wall element with the thickness of the wall precast member h=0.04 m. In the figure on the abscissa axis shows the total thickness of the wall element, mm, and on the ordinate axis–the total length.

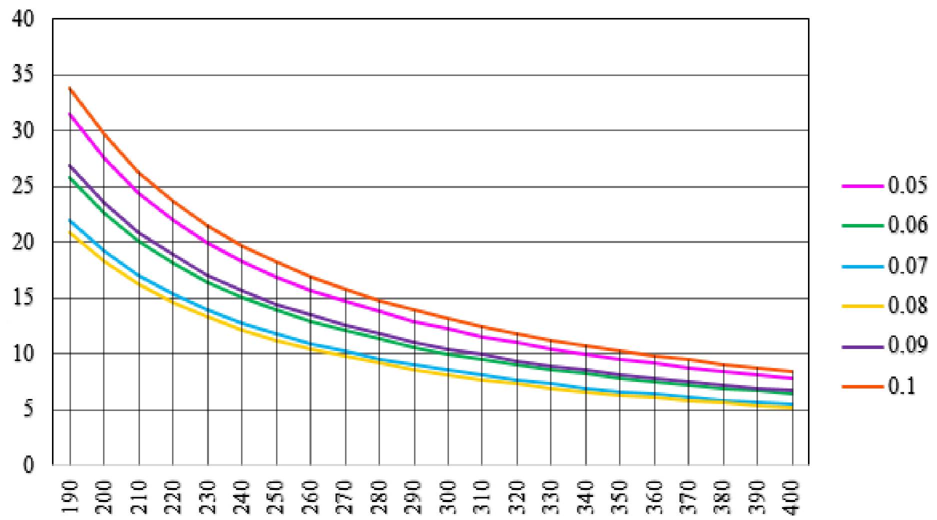

Figure 4. The dependence of the minimum total bay length on the thickness of the wall element with the thickness of the wall precast member h=0.05 m. In the figure on the abscissa axis shows the total thickness of the wall element, mm, and on the ordinate axis–the total length.

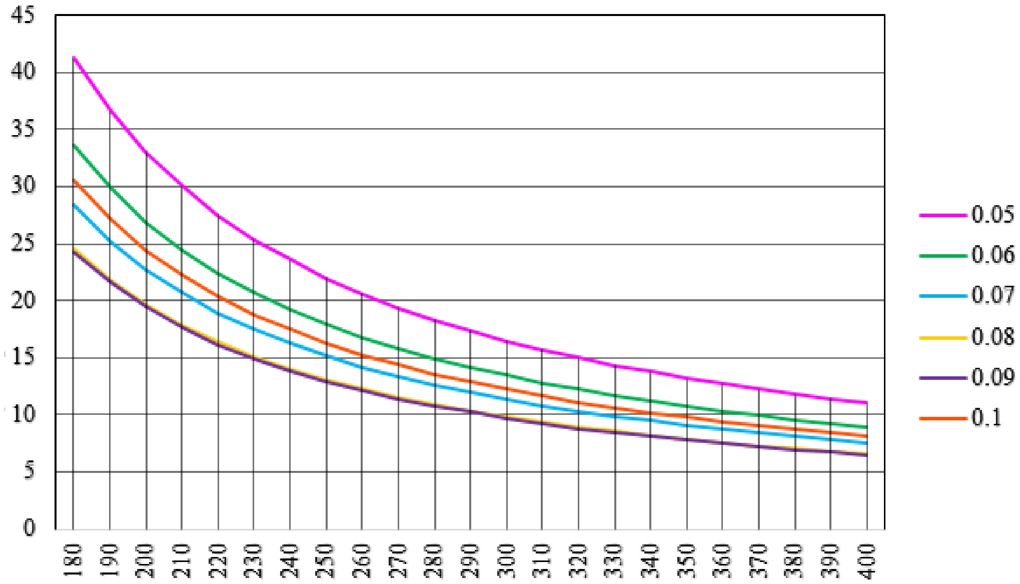

Figure 5. The dependence of the minimum total bay length on the thickness of the wall element with the thickness of the wall precast member h=0.06 m. In the figure on the abscissa axis shows the total thickness of the wall element, mm, and on the ordinate axis–the total length.

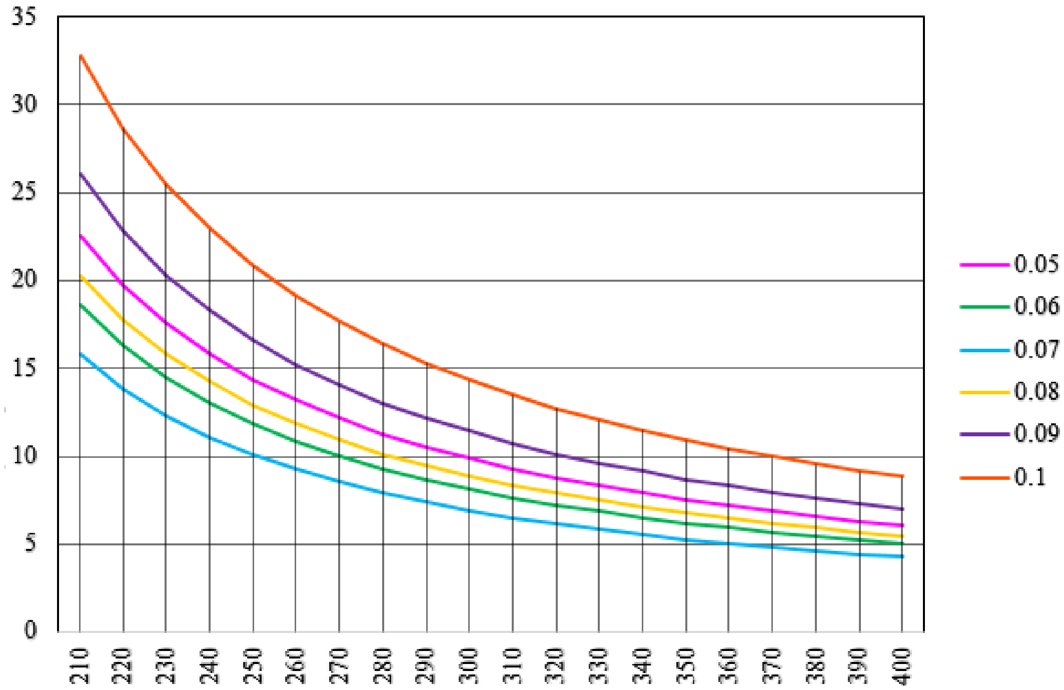

Figure 6. The dependence of the minimum total bay length on the thickness of the wall element with the thickness of the wall precast member h=0.07 m. In the figure on the abscissa axis shows the total thickness of the wall element, mm, and on the ordinate axis–the total length.

To make it more simple algorithm is made on DRAKON language. It shows the actions sequence without any detailed description (Figure 7).

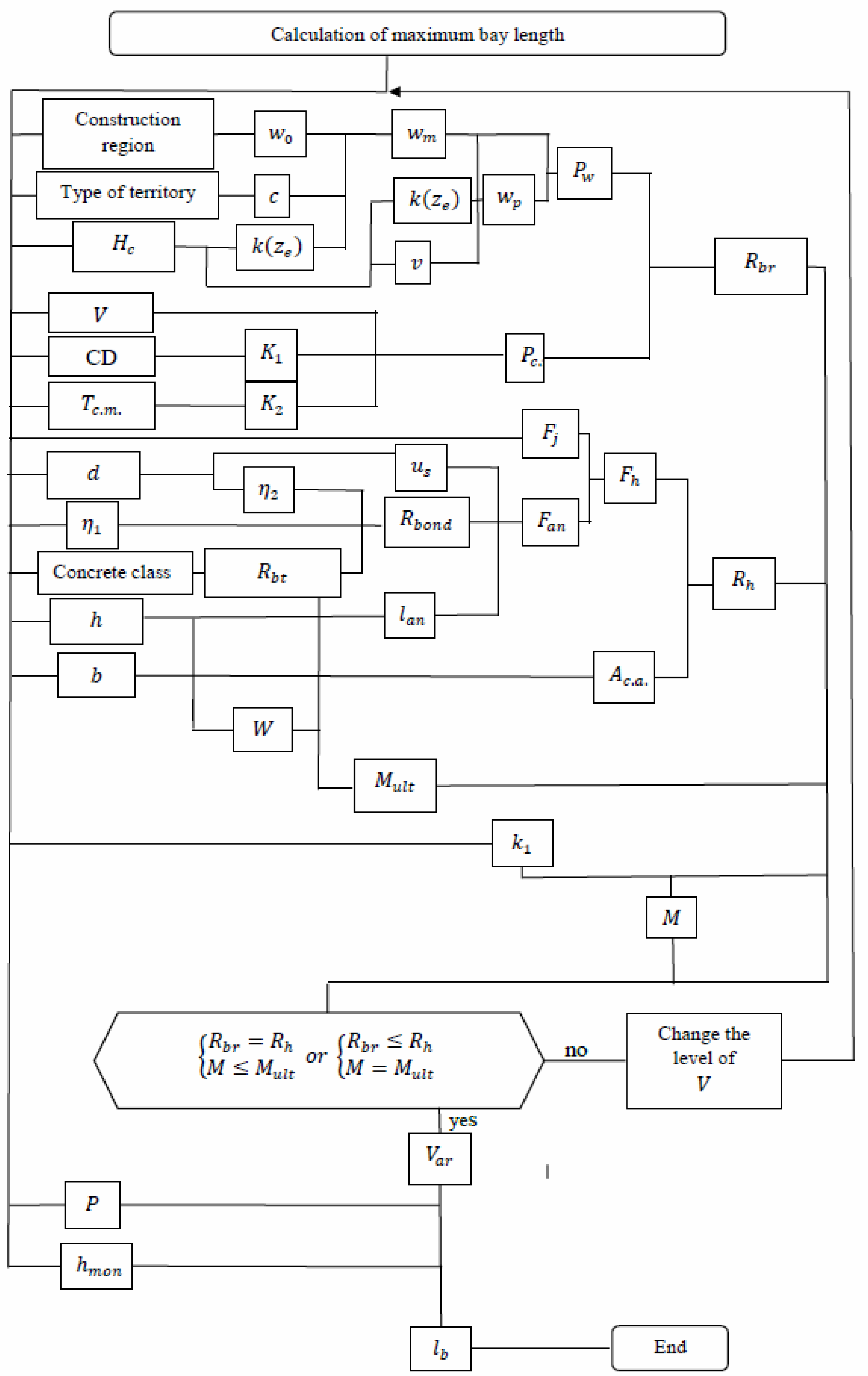

Figure7. Algorithm for calculation ofprecast-monolithic permanent formwork walls.

3. Conclusion

The graphs show the maximum bay length of the wall elements, concreted to the full height.

Note that the graphs also show the purposefulness of the possible choice of a particular step of the reinforcing cage at a given thickness of the precastmember. It makes sense to mention that the total thickness of the wall element is the sum of the thickness of the outer panels of the prefabricated element of a fixed wall panel, as well as a monolithic reinforced concrete part that fills the empty space between them, which clearly follows from Fig. 1.

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