

# Measures to reduce construction time of high-rise buildings

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**Abstract.** The organizational and technological solutions for high-rise buildings construction efficiency increase are considered, primarily – decrease of typical floor construction time and improvement of bearing structures concrete quality. The essence of offered technology is: a concrete mixing station and a polygon mainly for load-bearing wall panels with starter bars casting are located on the building site; for reinforced concrete components manufacturing and butt joints grouting the warmed-up concrete mixtures are used. The results of researches and elaborations carried out by the SPSUACE in area of a preliminary warming-up of concrete mixtures are presented. The possibility and feasibility of their usage in high-rise buildings and of excess height buildings construction including cast-in-place and precast execution are shown. The essence of heat-vibro treating of concrete mixture is revealed as a kind of prior electroresistive curing, and the achieved results are: accelerated concrete strength gain, power inputs decrease, concrete quality improvement. It is shown that the location of a concrete mixing station on the building site enables to broaden possibilities of the “thermos” method use and to avoid concrete mixtures warming up in medium-mass structures erection (columns, girders) during the high-rise buildings construction. It is experimentally proved that the splice between precast elements encased with warmed-up concrete mixture is equal with conjugated elements in strength.

## 1 Introduction

The most important constructional and technological peculiarity of buildings of excess height (25-30 storeys) and high-rise buildings (100-150 and more storeys) is its significant height excess on dimensions in plan. From this it follows that the construction time of its substructure massively depends on typical floor construction time. 5-6 working days per storey is considered to be acceptable result according to literature [1, 2]. From this it follows

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that the only substructure will be under construction about three years. Thus, a typical floor construction time decrease is quite an important task.

Because of limited sizes in plan decrease of typical floor construction time by means of compacting time schedules of different work types complete with traditional technologies is of little promise. The most typical floor construction decrease time effect may be got due to realization of organizational and technological conclusions being the point at issue of this article which are: location of a concrete mixing station and casting yard (mainly for wall panels manufacturing) on the building site; the warmed-up concrete mixtures usage for reinforced concrete components on site casting and butt joints grouting; concrete mixture preparation with 35<sup>0</sup>C - 45<sup>0</sup>C temperature at the polygon for medium mass structures concrete pouring and their subsequent maturing by using the “thermos” method.

There are substantiations of each listed organizational and technological solution below. It is important to note that only combined application of them enables to get the desired result that is typical floor construction time decrease of 1,5 - 2 days.

## 2 Methods

It is well known that the extra-strong concrete classes (B50-B80) are used for lower storeys construction and high-strength concrete classes – for upper storeys construction in high-rises building. Mentioned parameters of concrete physical and mechanical properties are estimated relatively (relative compressive, tensile, bending strength, etc.), what gives the opportunity to apply the lab and field tests results to concretes of different classes.

In addition to traditional (Gostovskaya) techniques, for example, GOST 10180-90 Concrete. Methods of determining strength on test specimens, for test of joint of precast-monolithic buildings was designed by a special technique. On active area of the “old” concrete which are the ends of combined panels the vertical inclined chases 4 mm wide and 6 mm depth were made. The concrete mixture of «new» concrete was warmed-up just before the placing with alternate electric current of industrial frequency (50 Hz) to + 50<sup>0</sup>C and + 70<sup>0</sup>C temperature and then placed with vibration in splice cavity. For «old» and «new» concretes samples shear testing postgraduate student Mustafin R.R. created special method excludes the appearance of the torsional moment about «old» and «new» concretes contact plane [3].

The essence of concrete mixture thermal treatment that is a kind of a preliminary warming-up, its rational application field, used materials, and the achieved effect are presented in writing [4]. It is important to note here that only application of warmed-up concrete mixtures made at site polygon enables to get concrete transport strength in minimum time with minimum power inputs and required concrete quality provided. The grouting of butt joints between precast elements with warmed-up mixture provides the equality in strength of the joint and conjugated elements [5, 6].

The feasibility of a concrete mixing station location on a site of a high-rise building construction, its parameters are substantiated in writings [7, 8].

## 3 Results

### 3.1. The mobile concrete mixing station (CMS) location on high-rise building site.

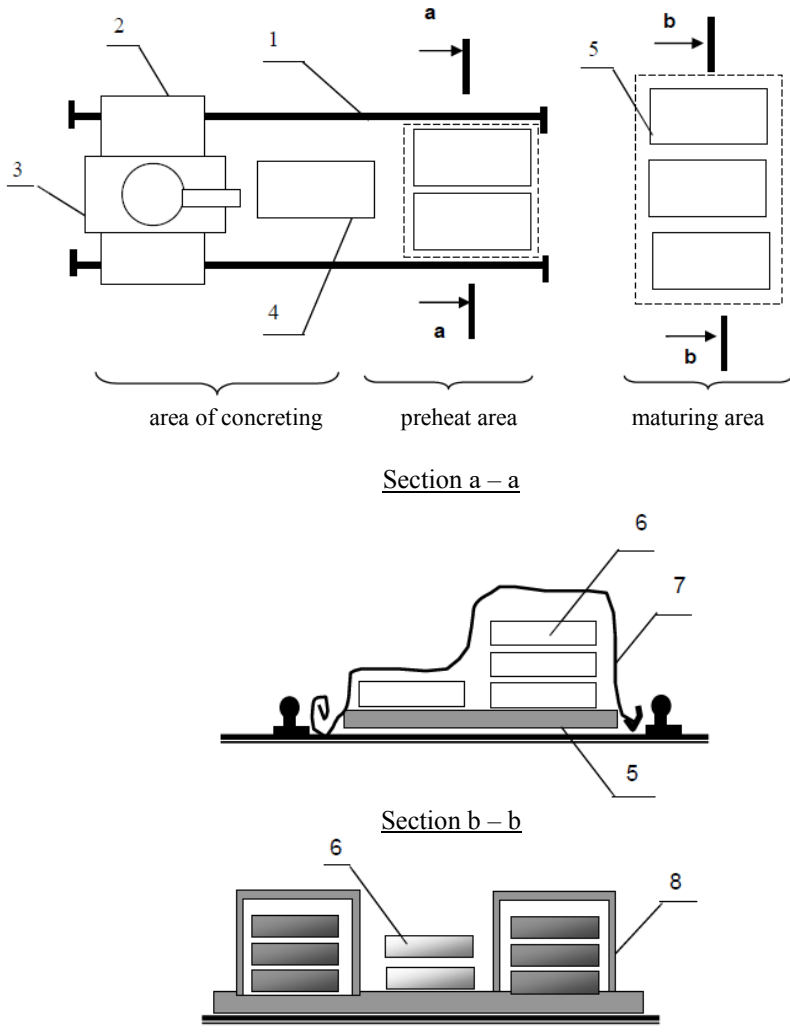
The mobile concrete mixing station (CMS) location on high-rise building site enables to provide:

- uninterrupted concrete mixture supply with no depending on the road traffic;

- delivery cost minimizing for concrete mix and prefab reinforced concrete fabricated at the site polygon;
- costs reducing for concrete on-site transportation, due to partly piping, for example.

### 3.2. The production of reinforced concrete products on the on-site test.

The production of reinforced concrete products on the on-site test site using heated mixtures is schematically shown in Figure 1. The daily turnover of the molds is provided by the heat introduced into the mixture when it passes through the HVTTCM device and the exothermic heat of the cement.



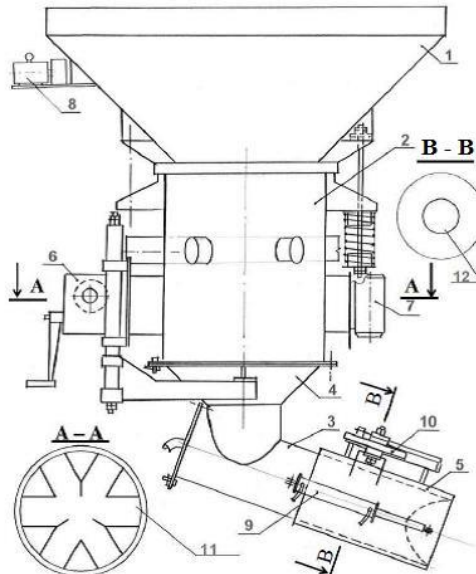
**Fig. 1.** Site casting yard scheme for combination of HVTTCM and thermoreactive curing:  
1 - rough track; 2 - self-moving portal; 3 – HVTTCM plant; 4 - structure under concreting; 5 - thermoactive footing; 6 - molded product; 7 - flexible heat seal packaging; 8 - thermoactive cap.

### 3.3. Heat-vibro treating of concrete mixtures.

Heat-vibro treating of concrete mixture (HVTM) is kind of preheating. Its essence is in continuous and overload (1 - 3 minutes) electrical curing of concrete mix along with vibration, extreme pressure and vapour exposure. Heatup and vibration are the main so the method of concrete mixture treatment and required equipment are called so. At that, vibration is used primarily as a way of concrete mix transportation during its treatment. Activating vibration property, vapour, excess pressure and electrostatic field action during electrical curing exerts in concrete characteristics improving, such as its strength against pure heating of concrete mix.

HVTM plant general form, which is recommended to use, is presented in Figure 2. System's critical components are: concreting hopper; vertical heating tube; inclined heating tube with catch; gate-operating mechanism and electrical box (OFC).

On internal surface of vertical tube current-collecting devices are electrically secured assigned, which connected to alternating current system with voltage of 380/220 V. Electrodes have a triangular cross section, at that adjacent electrodes are parallel. Inclined pipe body is neutrally assigned, electrically insulated central rod with circular current-collecting device are co-axial assigned inside the case. The plant works as follow. Traditionally made and transported to site concrete mix fills into hopper with fully closed gate. For the sake of internal volume filling with concrete mix and close contact between mix and electrodes procuring the vibrator turns on for 3-5 seconds. Then voltage is applied on electrode cells. After concrete mix temperature required value realization (near 70 - 80°C), after 1,5-2 minutes traps open and vibrator turns on. Further processing of the mixture proceeds in steady state. Since in such a short heating time the concrete mix to this temperature, the fluid body liquid phase is heated, and cement and sand grains from it, the coarse aggregate is heated later due to the thermal conductivity from the warm-up components of the mixture, so that after exiting the plant the average mix temperature falls by 5-20°C (depends on the aggregate size and its amount).

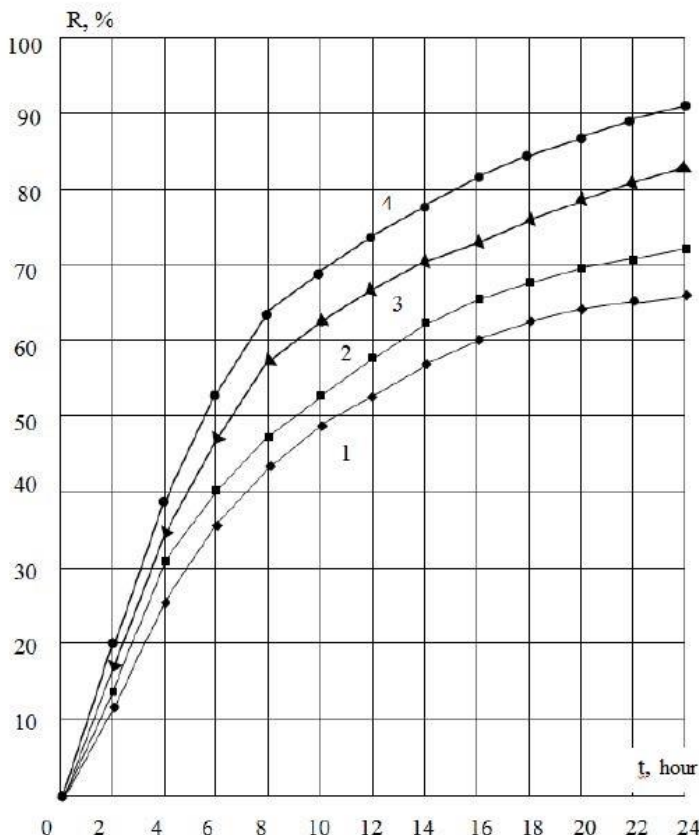


**Fig. 2.** HVTM plant general form. 1 - concreting hopper; 2 – vertical heating tube; 3 – inclined heating tube with reducing pipe 4; 5 - catch; 6 - elevator; 7 - vibrator; 8 - pumping set; 9 - hydrocylinder; 10 - synchronising linkage; 11 – triangular electrodes; 12 – circular electrodes.

Processes during heat-vibro treating of concrete mixture may be described this way. According to the Joule-Lenz law, when a current passes through a concrete mixture with an electrical resistance, heat is released in it. High temperature increases reaction of cement hydration. Vibration leads to deflocculating of cement grains, partly its dispergation, which is complemented by chemical dispergation. Concrete mix preheating is accompanied by partly vapour formation; and since treating passes in closed volume, this leads to excess pressure formation near 0.01 MPa. Water viscosity reducing with high temperature and vapour existence, which penetrability is greater than water, in combination with excess pressure keep to moisture penetration in cement grains. The combination of these effects intensifies chemical reactions, leads to an increase of cement mass, involved in the interaction with water.

The usage of heat-vibro treating concrete mixtures enables:

- strength gain increasing (40 – 50% of R28 after 6 – 8 hours, 70 – 100% of R28 after 24 hours) with 2 °C/hour cool-down rate (Figure 3);
- energy input minimizing (up to 50 kWh /m3);
- improvement of concrete quality for warm-up mixes against thermal curing for density, strength, concrete-to-steel bond;
- deletion of irretrievable electrodes losing, heating wire, which is unescapable during concrete curing;
- man-hour reducing for concrete maturing.



**Fig. 3.** Strength development for fresh concrete:  
1 – heat-vibro treating with 50° C; 2 – heat-vibro treating with 60° C; 3 – heat-vibro treating with 70° C; 4 – heat-vibro treating with 80° C.

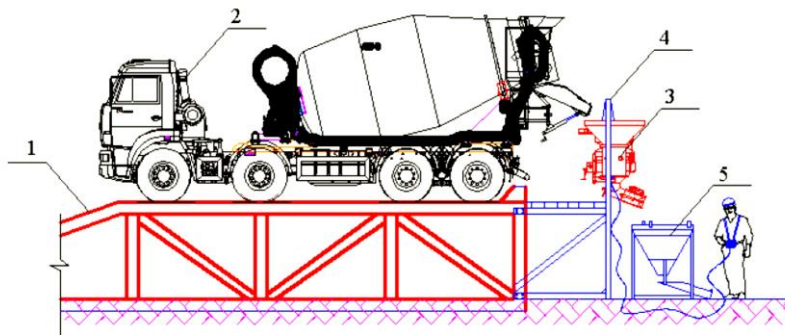
### 3.4. Embedment of joints between wall panels and floor slabs

Embedment of joints of reinforced concrete wall panels and slabs with overlap of the rebar, heating the concrete mix allows you to:

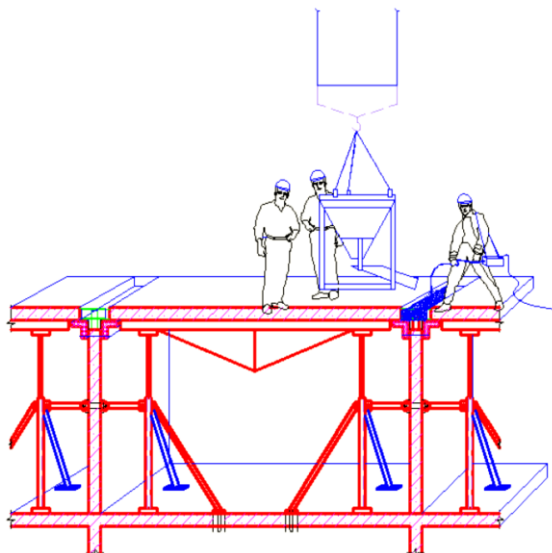
- providing the pace of cast-in-place and precast construction comparable to panel buildings;
- arc welding operations minimizing during construction period of residential unit;
- erection of prefabricated buildings, which model of structure is similar to cast-in-place buildings, that is safety and lifetime rising for dynamic loads or man-triggered actions;

To ensure the rate of concrete cooldown in the splice no more than  $2^{\circ}\text{C}$  per hour, the splice formwork must be thermally active. It was experimentally proved that combination of concrete mixture pre-heating before its laying in the splice, treating the active surface of "old" concrete and heating formwork, providing a cooling rate of concrete at a splice no more than  $2^{\circ}\text{C}$  per hour, It makes it possible to obtain splices of prefabricated-monolithic buildings with equal strengths with monolithic concrete with the shear works structure [3].

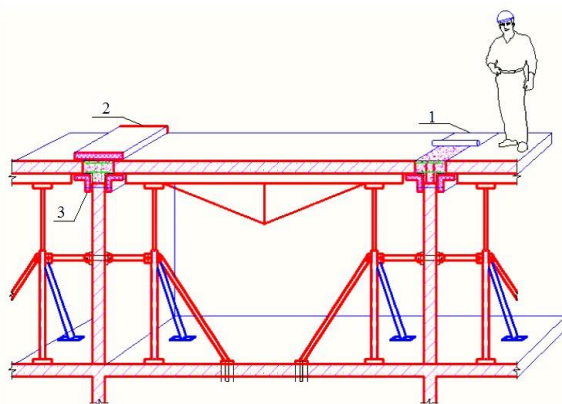
Butt joint grouting technology with warm-up concrete mixes for cast-in-place and precast construction, developed by Kolchedantsev L.M., Stupakova O.G. and Mustafin R.R., is following (Figure 4).



a) organization scheme for electrical curing. 1 – elevated road; 2 – mixer truck; 3 – pre-electric curing device for concrete mix; 4 – supporting frame; 5 – distributing hopper



b) concrete placing and poly-roll



c) splice hiding PF and TFC: 1 – polyfilm; 2 – thermoactive flexible coating; 3 – thermoactive coating (TAC)

**Fig. 4.** Key phases for splice making with warm-up concrete mixes.

After the wall panels rigging up the formwork with heating elements is being installed and with its help the butt joint heats to 15-20°C temperature. On the elevated road in assembly crane action area the HVTCM plant with under 2 m<sup>3</sup> per hour productivity is being set. The device may work with energy from diesel generator with 100-150 kVA power in case of freely installed power absence. Concrete mixture with plasticizing agents increasing time of warmed-up concrete mixture placeability maintenance added in making period is being uploaded from concrete mixer truck to the HVTCM plant receiving bunker.

There are three bunkers 0,5- 0,75 m<sup>3</sup> volume located in HVTCM plant location area below its deep pipes with batch gate. The bunkers are set on trolley frame that can move relative to the HVTCM plant. During the winter time the bunkers are insulated and equipped with hinged covers. After being filled with heat-vibro treated concrete mixture first bunker is transferred by crane to working horizon for grouting the butt joints. At the same time the concrete mixture is put from the HVTCM plant to the bunker №2. The bunker №3 is backup in case of some deviation from the continuous-cyclical schedule correlating the butt joints grouting process and HVTCM plant work.

The concrete mixture after heat-vibro treating is densifying with pervibrator in butt joints grouting process. After joint grouting its open surface is being covered with film. The required concrete maturing mode in joint is maintained with formwork with heating elements.

Floor butt joints are grouted the same way.

### **3.5. The setting of stiffening cores columns and girders provided spatial rigidity and overall stability of a high-rise building**

The formwork and reinforcement setting of these structures is performed with traditional technology. Considering these structures belong to medium or low-mass type the «thermos» method is recommended to apply for their grouting and maturing.

Considering the general orientation of this work, namely, the reduction of the time for the construction of high-rise buildings, and taking into account that the concrete-mixing unit is located directly on the construction site, the temperature of the concrete mixture output from the mixer may exceed the maximum permissible values specified in the Code of Practice SP 70.13330.2012 Bearing and enclosing structures, the updated version of SNiP 3.03.01-87. However, this recommendation can be implemented only after an experimental check of the timing of setting the cement at elevated temperatures.

## 4 Conclusions

Thus, the total effect of known technological solutions (concrete mixing station and polygons for floor and wall panels production location on a building site) in combination with a preliminary concrete mixtures warming-up applying for reinforced concrete elements production and grouting of the butt joints between them after their rigging up, and also the «thermos» method applying extension in medium and low-mass structures construction is in following: about 65-70% of high-rise building structures should be built not in the cast-in-place but in the precast and cast-in-place method that enables to decrease a typical floor construction time by 1,5-2 days.

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