Manufacturing full-size panels and frame-filings foam concrete by innovating technologies

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Abstract. This paper is devoted to development of a technological line, technological map and technology of production prefabricated large-sized partition panels and frame fillings on the base of a functioning manufacture prefabricated reinforced concrete products workshop. The territory of the Kyrgyz Republic is one of the most seismically active zones in the Central Asian region. More than 6.3 million people live in Kyrgyzstan. At the same time, the population living in the 9-point zone is about 1.0 million people (including 0.2 million people in Bishkek); in the 8-point zone – 5.1 million people, etc. In accordance with current design standards, the use of brick as frame infill above the fifth floor is prohibited. That’s why, there is a need to use alternative lightweight materials. The production of wall panels and frame fillings from foam concrete will significantly reduce the installation time of walls and significantly reduce the seismic load on the building.

1. Description of the tested product

The presented partition panels and frame fillings are constructed using a "waffle" principle - with a stronger and less porous layer of concrete on the outer surfaces of the product and a more porous interior. These products have a height ranging from 2500 to 2900 mm, a width of 600 mm, and a thickness of 100 mm. Two flat reinforcement grids made of Bp-1 class reinforcement wire with a mesh size of 125x135 mm are installed in the products, positioned 10 mm from the external surfaces. At the bottom of the panels, angle brackets measuring 35x35 are laid. The actual reinforcement scheme of the panels is shown in Figure 2. The products are joined together with a tongue-and-groove type joint known as "male-female" (Figure 1).

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**Fig. 1.** Tongue-and-groove joint of the "male-female" type

**Fig 2.** Reinforcement scheme of the product with a thickness $\delta = 100$mm.

### TABLE 1

<table>
<thead>
<tr>
<th>The thickness of the product</th>
<th>Grade, quantity of grids</th>
<th>№</th>
<th>Sketch</th>
<th>$\varnothing$, mm</th>
<th>Length, mm</th>
<th>Quantity of pieces.</th>
<th>Total length, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mm</td>
<td>SP-1 (piece 1)</td>
<td>1</td>
<td></td>
<td>580</td>
<td>4Bp-1</td>
<td>21</td>
<td>24,36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>2880</td>
<td>4Bp-1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

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**2. Production technology of foam concrete panels using the classic (with the use of a foaming agent) non-autoclaved technology**

1. Preparation of the foaming agent solution: The foaming agent is the active substance used in production to create porous cellular concrete. To prepare the foaming agent solution, a foam concentrate is used in a ratio of 1:30 with water and mixed twice with a 15-minute interval in a clean container. Then, the foaming generator is adjusted as follows:
   - Turn on the compressor.
   - Lower the hose of the foaming generator pump into the container with the foaming agent solution.
   - Set the air pressure regulator of the steam generator to 2-6 atm.
   - Turn on the foaming generator pump on the control panel and open the foam supply valve after 20-30 seconds. Collect the resulting foam in a one-liter container and weigh it. The weight of the ready foam should be within 40-60 g/l.
   - Turn off the pump and close the valve.
   - If necessary, adjust the weight of the foam by increasing or decreasing the air pressure.

2. Preparation of foam concrete mix and molding:
   - Under the guidance of the master, a lubricated formwork is assembled, and reinforcement grids and wire fasteners are installed.
   - Water is poured into the mixer through a dispenser for one batch (the operator sets the dosage value for one batch on the dispenser and presses the "START" button). Once the specified volume of water is supplied, the water delivery is automatically stopped. The mixer drive is turned on.
   - Fibrous material is loaded into the mixers.
   - Sand and cement are loaded into the mixers (the operator enters the dosage values for cement and sand for one batch and activates the "Dosage" mode). After the "Unload" lamp lights up, the operator presses the corresponding button, and the materials from the dispensers are fed into the mixer. After unloading the materials into the mixer, the cycle of loading the dispensers with cement and sand is repeated.
   - The solution is mixed for 1-2 minutes.
   - The foam generator pump is turned on, and the foam supply valve is opened.
   - The entire volume of the mixer is filled with foam up to the loading hatch rim.
   - The foam concrete mixture is mixed for 1-2 minutes.
   - For molding, the operator opens the mixer's drain valve, and the mixture is discharged into the mold through a hose. Once the entire mixture is discharged, the mixer's valve is closed. This cycle is then repeated, and the time interval between batches should not exceed 40-50 minutes. Otherwise, the mixer and feeding hoses need to be cleaned. The filled mold is moved to the curing chamber on a trolley.
   - The curing time in the chamber is set by the master depending on density, cement activity, and temperature. The temperature in the chamber is maintained at 40-60°C.
   - After curing, the trolley with the formwork is moved to the demolding area under the master's command, and the finished products are then sent to the curing area.

3. Demolding of Products:
   - The demolding of products is carried out directly under the supervision of the master.
   - Ensure the proper functioning of the trolley mechanism carrying the formwork.
   - Move the trolley from the drying chamber to the demolding station. Remove the fastening elements, fixators from the outermost formwork, and the formwork itself.
   - Remove the finished products (2 pieces at a time) using a crane beam and place them on a cassette, using safety belts during demolding.
   - Continue to remove the remaining products sequentially.
After passing the quality control inspection by the Quality Control Department (QCD), the finished products are moved from the product curing area to the finished product storage area using a trolley.

4. Quality Requirements:
   Visual inspections are carried out, and the following imperfections are not allowed:
   - Chipping and blunting of corners and edges exceeding a length of 20mm and a depth of 10mm.
   - Deviation of the plane and edges by more than 5mm.
   - Delamination, voids, cracks, and foreign inclusions.

5. Care of Molds and Equipment After Work Completion:
   - The bases and edges of the molds are cleaned from cement deposits and remaining solution residues.
   - The molds are disassembled and sent for lubrication.
   - Equipment is powered off, and the work area, mixer, and other equipment are cleaned from dirt and remaining solution residues.

6. Cleaning of the Foam Generator:
   - Fill a clean container with 20-30 liters of water.
   - Lower the hose of the foam generator pump into the container, turn on the pump (press the "Turn on Foam Generator" button), and wait until clean water without foamy inclusions comes out.

7. Cleaning of the Mixer:
   - Rinse the internal surface of the mixer and the auger with water. After cleaning, drain the water

**TABLE 2.** Organization of the technological manufacturing process
<table>
<thead>
<tr>
<th>Sequence of Operations</th>
<th>Workers</th>
<th>Safety instructions</th>
<th>Mechanisms, equipment, tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demolding of Products:</td>
<td>Master, molder, neger.</td>
<td>It is forbidden to work with faulty lifting devices. When transporting products, one should be positioned away from the direction of product movement. Use safety belts.</td>
<td>Crowbar, overhead crane, scraper, wrench, casing, safety belt.</td>
</tr>
<tr>
<td>Remove the casing. Loosen the bolts. Remove the outermost fixators and the outermost formwork. Sling two products and place them on the stand for curing, finishing, and inspection. In the same order, remove the fixators, formwork, and products.</td>
<td></td>
<td>It is forbidden to work with faulty lifting devices. Make sure the lifting devices are in good condition before use.</td>
<td>Trash bin, scraper, broom, safety goggles, dustpan.</td>
</tr>
<tr>
<td>Move the casing to its designated location. Demold the products. Lift the products smoothly without jerking.</td>
<td>It is necessary to clean the surfaces of the formwork elements and form shields from adhered foam concrete. To avoid eye contamination during cleaning, one should work while wearing safety goggles. Trash, gloves immediately removed after cleaning. Work with gloves.</td>
<td>Container with lubricant, brush, small brushes, roller.</td>
<td></td>
</tr>
<tr>
<td>2. Cleaning of Molds:</td>
<td>Molder</td>
<td>Walking on the surfaces being lubricated is prohibited. Lubricants should not contain harmful substances.</td>
<td>Container with lubricant, brush, small brushes, roller.</td>
</tr>
<tr>
<td>Cleaning molds from residual foam concrete and dust.</td>
<td>Pgo. special attention to cleaning the formwork and the formwork elements (lamellas and shields).</td>
<td>Apply the lubricating compound using small brushes and rollers. Recommended lubricant - TiraLux or equivalent.</td>
<td></td>
</tr>
<tr>
<td>3. Lubricating the Molds:</td>
<td>Molder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lubricate the mold using the mold oiling device.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
4. Form Assembly: Cleaned and lubricated forms should be assembled on a transport trolley and prepared for the installation of reinforcement frameworks. Sequence: in reverse order of the demolding process.

- Overhead crane, crowbar, wrench, safety belt.

It is prohibited to use faulty lifting devices.

Use safety belts.

5. Reinforcement: Place the frameworks into the assembled molds, secure fixators for maintaining the protective layer of foam concrete, and safety fixators.

Forms should meet the requirements for stiffness and vertical deformability. The installation of reinforcement frameworks should be carried out in accordance with the working drawings.

- Racks for storing reinforcement frameworks, lifting loops, overhead crane, hammer.

Reinforcement of structures should be carried out in a way that eliminates the possibility of injury. Use safety belts.

6. Molding: Foam concrete is delivered through a hose from the foam concrete mixing unit. The molding process also includes the preparation of the foam. After molding, the concrete mixture is rinsed and cleaned.

- Foam concrete, container for measuring foam density, scales, molds for forming samples - cubes, ruler, shovel and bucket.

For safe work during the foam concrete pouring, the platform of the pit is equipped with a fenced area. Access to the platform is provided via an attached ladder. It is prohibited to work on malfunctioning equipment, platforms, and ladders.
| 7. Heat Treatment: Close the casing with the products, then roll the trolley into the chamber, and apply heat according to the heat treatment cycle developed by laboratory specialists, depending on the ambient temperature. | During the curing process, the temperature in the chamber should be maintained within the range of 40-60°C. | Casing made of dense material, heater, thermometer, trolley. | It is prohibited to work with malfunctioning electrical tools and equipment, as well as for personnel to be located on top of the formwork or casing. | master, foreman, molder | 1 | 1 | 1 |
TABLE 3. Technical requirements for materials

<table>
<thead>
<tr>
<th><strong>List of raw materials, materials, and semi-finished products. Abbreviation: ND.</strong></th>
<th><strong>Technical requirements imposed on raw materials, materials, and semi-finished products.</strong></th>
<th><strong>Storage method.</strong></th>
<th><strong>Note</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete GOST 30515-2013</td>
<td>Portland cement М400 or М500</td>
<td>During transportation and storage, it should be protected from moisture and contamination by foreign impurities.</td>
<td></td>
</tr>
<tr>
<td>Sand GOST 8736-2014</td>
<td>Sieved sand with a 5 mm sieve, grade М 1.5-2.0, bulk density 1.35-1.45 t/m³. Washed sand with impurities not exceeding 2% according to the manufacturer's specifications. GOST 8736-2014</td>
<td>Under the shelter</td>
<td></td>
</tr>
<tr>
<td>Foaming agent IFomex</td>
<td>Compliance with the certificate.</td>
<td>Protection from direct sunlight</td>
<td></td>
</tr>
<tr>
<td>Water GOST 23732-2011</td>
<td>Water should not contain impurities in quantities that disrupt the setting and hardening times of cement mortar and foam concrete, reducing the strength and frost resistance of foam concrete (distilled or drinking water).</td>
<td>Closed containers</td>
<td>The water temperature during the mixture preparation should be set according to the laboratory recipe</td>
</tr>
<tr>
<td>Reinforcement and anchor details GOST 5781-82* GOST 10922-2012 GOST- 6727-80</td>
<td>Reinforcement frameworks, GOST 10922-2012</td>
<td>Under the canopy, in the workshop on racks</td>
<td></td>
</tr>
</tbody>
</table>
Fig 3. Schedule of heat treatment for non-autoclaved cured foam concrete panels

1. Heating up to 60°C - 6 hours.
2. Holding the products in the chamber at a temperature of 60°C - 24 hours.
3. Turning off the heat and keeping the products in the chamber - 4 hours.

The total heating regimen amounts to $6 + 24 + 4 = 34$ hours.
Fig 4. Typical technological scheme for the production of non-autoclaved foam concrete.
Fig 5. The plan for the technological line

Fig 6. The scheme for the production of foam concrete
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