



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**09.03.2011 Bulletin 2011/10**

(51) Int Cl.:  
**B28B 1/08 (2006.01) B28B 3/22 (2006.01)**

(21) Application number: **10174989.3**

(22) Date of filing: **02.09.2010**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**  
Designated Extension States:  
**BA ME RS**

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(30) Priority: **02.09.2009 FI 20095902**

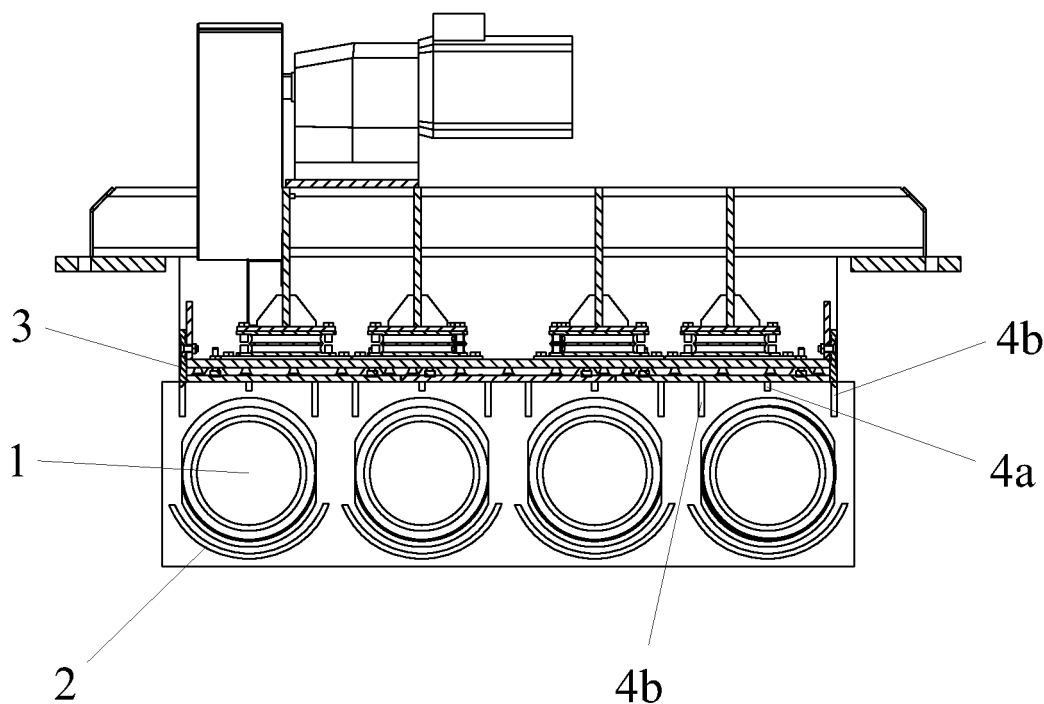
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(54) **Apparatus and method for casting a concrete product by slipform casting**

(57) The invention relates to a slipform casting apparatus, comprising at least one feed screw (1) and at least one guide element (4) for balancing the supply of

concrete mix between the top and bottom surfaces of the concrete product to be cast, in which apparatus at least one guide element (4) is placed in a troweling beam (3) at and above said at least one feed screw (1).



**FIG. 1**

## Description

**[0001]** The invention relates to an apparatus and method for casting concrete products by a substantially horizontal slipforming technique, where concrete mix is fed through a restricted transversal surface for manufacturing a concrete product with a desired shape. More precisely, the invention relates to intensifying the concrete mix feed of at least one feed screw used in the casting process, and to improving the feed balance.

**[0002]** Currently used slipform casting arrangements are generally based either on the extruder or the slip-former technique. In conventional extruder type casting machines, concrete mix is fed from the concrete mix container under hydrostatic pressure onto feed screws, which feed screws extrude the concrete mix by intermediation of both rotary and reciprocating motion through a restricted transversal surface in order to obtain a concrete product with a desired shape. When casting hollow-core slabs, the feed screw is provided with a core-forming mandrel that creates a hollow core in the product to be cast. Moreover, the entity formed by the feed screw and the core-forming mandrel also performs a reciprocating compacting motion for compacting the concrete mix. Underneath the feed screw, and partly around it, there is arranged a feed trough for guiding the concrete mix around the core-forming mandrel. On top of the core-forming mandrel, and partly also on top of the feed screw, restricting the top surface of the product to be cast, there is located a top surface compacting beam that comprises a back and forth moving troweling beam for compacting and leveling the top surface of the cast product. The sides of the cast product are in the longitudinal direction defined by back and forth moving side walls, the motion whereof compacts and levels the side surfaces of the cast product. The casting apparatus moves along the casting bed owing to the effect of the reacting force of the feed screws, resting on the wheels provided in the apparatus. Moreover, a separate actuator can be provided for balancing the speed of the casting arrangement. The ready made casting product remains on the casting bed.

**[0003]** In solutions based on the slipformer technique, concrete mix is fed, along with the casting process, first to the lower part of the mold formed by the side walls moving along with the casting machine and the casting bed. As the casting process proceeds, said first feeding of concrete mix is followed by the use of vibrating shoes, which by vibrating the mix compact the concrete mix cast in the mold and form hollow cores in the product as regards the already supplied concrete mix. After the vibrating shoes, there are arranged core-forming mandrels that ensure the formation of a hollow core in the cast product. On top of the end part of the core-forming mandrels, there is fed a second supply of concrete mix for casting the top part of the product to be cast, and this concrete mix is compacted by means of a vibrating plate placed on top of the end part of the core-forming mandrel. The ready made product remains on the casting bed.

**[0004]** In a combined extruder and slipformer casting method, the concrete mix flows from the concrete mix container onto feed screws that feed concrete mix around the vibrating shoes. The vibrating shoes compact the concrete mix by vibration and form preliminary hollow cores in the product to be cast. After the vibrating shoes, there are arranged core-forming mandrels for ensuring that the hollow core maintains the desired form also when the vibrating effect is settling. The progress of the casting apparatus is realized by a separate driver.

**[0005]** Generally slipforming techniques are used for manufacturing long products that are sawed into suitable lengths after the casting is cured.

**[0006]** In casting arrangements comprising a feed screw, the operation of the feed screw is based on the fact that it generates in the concrete mix located at the thread of the feed screw a force in the direction of the longitudinal axis, which force moves the mix forward. Depending on the pitch of the thread, the concrete mix is also subjected to a force that is effective in the rotary direction of the feed screw, i.e. a force that is perpendicular to the force mentioned above. Said force attempts to rotate the concrete mix around the feed screw. Underneath the feed screw of the extruder, there is arranged a concrete mix feed trough that generates a shear force in the concrete mix. Said shear force prevents the mix from rotating along with the feed screw, which means that the mix moves forward. Naturally the shear force also affects in the longitudinal direction, but it is not sufficient for cancelling the force created by the feed screw.

**[0007]** Above the feed screw, there is arranged a troweling beam, but it is located further away from the screw, and it makes a troweling motion. It has occasionally been found out that in cast concrete slabs obtained as end products, there is formed a depression in the slab cover over the hollow cores. This may be due to poor compacting of the mix on top of the hollow core, which in turn may be a consequence of the fact that above the feed screw, the mix can also move in the transversal direction with respect to the feed direction, i.e. that component in the speed vector of the mix that is parallel to the casting direction is on the lower half of the screw larger than on the upper half.

**[0008]** From the Finnish patent publication FI 118 175, it is known to use eccentric feed screw, by means of which the compacting of the concrete mix can be intensified, particularly in the lower part of the product to be cast. This is based on an alternating expansion and reduction of the space left in between the screws, and of the space left in between the screw and the concrete mix feed trough, due to the eccentric nature of the feed screws. As the above mentioned intermediate spaces are at largest, they are filled with flowing concrete mix, and as the feed screws continue rotating, the concrete mix left in between them is compressed and compacted.

**[0009]** The patent publication EP 1 398 128 describes a method and arrangement where in a substantially horizontal slipform casting of a concrete product, the relative

proportion of the concrete mix flow in the top part or bottom part of the product is adjusted by shifting or tilting the concrete mix feed trough located underneath the feeder elements.

**[0010]** From the patent publication US 4,773,838, it is known to improve the compacting of concrete mix in a casting mold by moving mold walls provided with protrusions in a reciprocating, synchronized motion. In this casting apparatus, at least two opposite mold walls are provided with protrusions projecting into the mix. The purpose is to tamp the concrete mix more compactly in the mold element. The essential feature is the reciprocating motion of the mold walls provided with protrusions, which generates the motion and compacting of the mix. According to the embodiments described in said publication, when the protrusions are wide in the transversal direction, extending even over the width of the slab, the reciprocal and synchronized motion of the mold walls takes place in the longitudinal direction. On the other hand, when the protrusions are sharp and narrow, the motion takes place in the transversal direction.

**[0011]** The Finnish patent publication 48902 describes a slipform casting machine where guide plates are arranged in between the feed screws in order to prevent the mix from rotating along with the screws. The guide plate extends along the whole length of the threaded part of the feed screw. The plate can also be provided with vibration.

**[0012]** By means of a solution according to the present invention, there is realized an apparatus by which the balance in the feeding of concrete mix is improved, i.e. the distribution of the mix between the upper and lower surfaces of the element to be cast is controlled so that a sufficient quantity of mix is obtained also in the top half of the element. At the same time the compacting of the mix is improved, particularly in the top half of the concrete product. Moreover, the balance in the feeding of concrete mix can be improved in the transversal direction of the product to be cast.

**[0013]** An apparatus according to the invention comprises at least one element arranged above the feed screw, in the top part of the defining surface, i.e. in the troweling beam, which element controls the motion of the concrete mix, compacts it and simultaneously balances the distribution of the mix between the upper and lower halves of the product to be cast.

**[0014]** The apparatus and method according to the invention can be applied in all types of slipform casting arrangements that include at least one feed screw.

**[0015]** More precisely, the apparatus according to the invention is characterized by what is set forth in the characterizing part of Claim 1, and the method according to the invention is characterized by what is set forth in the characterizing part of Claim 11.

**[0016]** The invention is described in more detail below, with reference to the appended drawings, where

cross-section of an embodiment of an extruder slipform apparatus according to the invention, viewed from the back along the line, and

Figure 2 is a schematical illustration of the embodiment of Figure 1, viewed from the side.

Figures 3 (a) - 3 (d) are schematical illustrations of various different models of guide elements according to the invention, as viewed from the side (a), (b) and (c), and as viewed from the top (d).

Figures 4 (a) - 4 (c) are schematical illustrations of various embodiments of the invention, where the guide element or elements are inclined with respect to a defined vertical plane.

Figure 5 is a schematical illustration of an embodiment of the invention, as regards one guide plate, viewed from different directions (a), (b) and (c), in which embodiment the direction of inclination of the guide plate is changed.

**[0017]** The essential elements of the embodiment of an extruder slipform casting equipment according to the invention, illustrated in Figures 1 and 2, are feed screw 1, their number in Figure 1 being four, concrete mix feed trough 2, top troweling beam, i.e. compacting beam 3, elements 4a and 4b for balancing the concrete mix feed, concrete mix container 5, core-forming mandrel 6, actuator 7, side walls 8, casting bed 9 and mass plate 10.

**[0018]** In the extruder-type slipform casting machine illustrated in Figures 1 and 2, concrete mix is fed from the concrete mix container 5 under hydrostatic pressure onto the feed screws 1, which extrude the concrete mix by a rotary and reciprocating motion in the mold defined by the casting bed 9, the side walls 8 and the top troweling beam 3. When casting hollow-core slabs, as in the examples of Figures 1 and 2, at the end of the feed screws are attached core-forming mandrels 6, which perform a reciprocating motion together with the feed screws, and thus form hollow cores in the concrete product to be cast. Underneath the feed screws, there are set concrete mix feed troughs 2 to intensify the concrete mix extrusion carried out by the feed screws, and to guide the concrete mix on the lower surface of the product to be cast. The concrete mix feed troughs 2 do not extend to the area located in between the screws, with makes it possible to use top strands. According to the present invention, also above the feed screws there are provided control elements, which in the case of Figures 1 and 2 are guide plates 4a and 4b. Said guide plates 4a and 4b attached to the top troweling beam 3 balance the concrete mix feed, so that a sufficient quantity of concrete mix is obtained both on the top and bottom surfaces of the product to be cast. In addition, the guide plates 4a and 4b set in troweling motion compact the concrete mix during the casting process. In this context, the top surface of the cast product during the casting process refers to that part of the product surface that faces the top troweling beam 3 and/or the concrete mix container 5, and the bottom surface of the cast product in turn refers to the opposite

Figure 1 is a schematical illustration representing a

surface that faces the casting bed 9.

**[0019]** In this specification, the guide element according to the invention is generally referred to with the reference number 4. In Figures 1 and 2, the reference numbers 4a and 4b are used for the guide plates, because the sizes of the plates vary in different locations of the screw. In these drawings, 4a refers to the guide plate located in the middle of the feed screw, and 4b refers to the plates located at the edges, which plates are mutually identical. The number of guide elements 4 per feed screw can be one or several. It or they are always located at the screw, placed above it, and not for example in the area left between two separate screws.

**[0020]** Three different dimensions are defined as follows for the guide element 4 according to the invention: the length of the guide element refers to the dimension defined in the longitudinal direction of the feed screw; the width or thickness of the guide element refers to the dimension defined in the transversal direction of the feed screw; and the height of the guide element refers to its dimension in the vertical direction.

**[0021]** According to the invention, the guide element 4 is fastened to the troweling beam 3, and moves along with the troweling motion of the beam in a reciprocating motion, thus compacting the concrete mix during the casting process. The fastening is carried out so that there is substantially no gap left between the troweling beam 3 and the guide element 4.

**[0022]** According to the invention, the length of the guide element or elements 4 may vary within the area that begins halfway to the vertical channel formed by the mass plate 10 and the troweling beam 3 and ends at the end of the threaded part of the feed screw 1, i.e. at the core-forming mandrel 6. In the longitudinal direction, the guide element may cover for example about 30% of the width of the vertical channel, and extend to a distance of 100 - 200 mm from the end of the threaded part of the feed screw 1.

**[0023]** The height of the guide element 4 in the area of the troweling beam is defined on the basis of the distance between the troweling beam and the feed screw, so that there is substantially no gap left between the guide element 4 and the troweling beam 3, and it extends to near the threadings of the feed screw; the distance from the threadings may be 0 - 50 mm, preferably 5 - 10 mm. Said distance remains substantially the same throughout the threaded part of the feed screw.

**[0024]** As is apparent from the embodiments illustrated in Figures 2 and 3, the guide element 4 extends, at the vertical channel formed by the troweling beam 3 and the mass plate 10, above the surface of the troweling beam 11 for the length  $L_1$ .  $L_1$  may also be zero, in which case the guide element continues, at the height of the surface 11 of the troweling beam also at said vertical channel.  $L_1$  can be 0 - 300 mm; preferably it is 50 - 200 mm and more preferably 100 - 150 mm.

**[0025]** At said vertical channel, the angle of the guide element can be inclined to a suitable degree (Figure 2).

On the other hand, also a sharp angle is possible (marked by a dotted line in Figures 3 (a) - 3 (c)).

**[0026]** In shape, a guide element 4 can be a plate 4a and 4b illustrated in Figures 1 and 2. The number of guide plates per feed screw is optimized appropriately. In the embodiment according to Figures 1 and 2, the number of guide plates per one feed screw is three, and they conform to the shape of the screw 1 both in the longitudinal and transversal directions thereof. The number of guide plates 4a and 4b can be for example one to twelve, in the direction of the transversal axis of the feed screw, preferably 1 - 5 and more preferably 2 - 3. The thickness of the guide plate can vary within the range 3 - 15 mm, and preferably it is 5 - 8 mm. The guide plate must be sufficiently rigid in structure, so that it endures the strain caused by the concrete mix without bending.

**[0027]** The fact that the guide element 4 conforms to the feed screw 1 in the longitudinal direction means that the distance of the element 4 from the feed screw remains substantially the same along the whole width thereof. As is apparent from the schematic figure 2, the guide plates 4a and 4b become lower as the diameter of the feed screw becomes longer. The fact that the element 4 conforms to the feed screw 1 in the transversal direction means that the distance of said element from the feed screw remains substantially the same in the transversal direction of the screw. In the embodiment illustrated in Figures 1 and 2, i.e. with separate guide plates, this becomes apparent in that the plate 4a located at the middle of the screw is throughout lower than the plates 4b located at the edges of the screw. Depending on the shape and structure of the guide element 4, its design conforming to the feed screw 1 can be realized in various different ways.

**[0028]** According to an embodiment, the guide element 4 is a guide plate, the lower edge of which is provided with cogs or dents which, in addition to their guide function, also effectively compact the concrete mix. The side profile of a guide plate according to this embodiment is illustrated in Figure 3 (c). On the other hand, at least one of the side edges of the guide plate or plates may be provided with cogs of the same type. Figure 3 (d) is a schematic illustration of this kind of guide plate, viewed from the top, which is provided with cogs at both side edges. The number of these dented guide plates in the direction of the transversal axis of the feed screw is the same as was earlier defined in connection with a guide plate with straight edges.

**[0029]** According to another embodiment, the guide element 4 can be a row of bars or pins in shape, so that said row of pins is attached to the troweling beam and conforms to the shape of the feed screw in the longitudinal direction. It could for instance be possible that the plates of Figures 1 and 2 were replaced by rows of bars, as is schematically illustrated in Figures 3 (a) and 3 (b). The bars may be placed in straight rows, or they may form a zigzag pattern. The number of bar rows in the longitudinal direction of the screw can be equal to the

number of guide plates, and they conform to the shape of the screw in the transversal direction in a corresponding way. The number of separate bars per each row of bars may vary, and it can be defined by a man skilled in the art, for example on the basis of the structure of the equipment and the shape of the bars. In cross-section, a bar or pin can be for example a lozenge, a rectangle, a square, a circle, an oval or a droplet. The bars are placed so that their balancing effect on the concrete mix feed is as intensive as possible, for example in the case of a lozenge the sharp corner is directed forwards, symmetrically in the direction of the flow. When viewed from the side, a bar can be a half-ellipse, a circle, a triangle, a rectangle or some other shape. The measures of a bar row or rows in the longitudinal direction and in the height and width directions, with their fluctuation ranges, are equal to those earlier defined in connection with plates.

**[0030]** The guide plates, bars/bar rows or guide elements with some other shape are typically installed substantially in parallel with the vertical plane proceeding in the direction of the central axis of the feed screw. According to the invention, it is also possible that at least one guide element is inclined with respect to the vertical plane proceeding in the direction of the central axis of the feed screw. The inclination may take place both in the horizontal and vertical direction with respect to the defined vertical plane. Figures 4 (a) - 4 (c) represent schematical illustrations of various different embodiments according to the invention, where the position of the guide elements differs from the defined vertical plane. According to the embodiment illustrated in Figure 4 (a), those guide elements 4b that are located farthest at the edges are inclined with respect to the vertical direction of the defined vertical plane, so that each deviates from it to the same degree, but in opposite directions. The guide element 4a located in the middle is substantially parallel to the vertical plane. The guide plates 4 described in the embodiment of Figure 4 (b) deviate from the defined vertical plane in the horizontal direction. Also in this embodiment, the angle of inclination is identical with both plates, but in opposite directions. In the embodiment illustrated in Figures 4(c) and (c'), the angle of the pins constituting the guide element 4 is in the area of the vertical channel different from the angle located underneath the troweling beam. In the area of the vertical channel, the pins are inclined in the vertical direction of the defined vertical plane (Figure 4(c')). On the other hand, below the troweling beam 3, the pins are inclined, with respect to the plane passing via the front edge 12 of the troweling beam, in the direction of the concrete mix flow.

**[0031]** According to an embodiment, the tilt angle of the guide plate can change along the width thereof, i.e. for instance in the area of the vertical channel formed by the mass plate 10 and the troweling beam 3, it may be different than below the troweling beam 3. Figure 5 represents a schematical illustration of one such embodiment, as regards one guide plate 4. Figures 5 (a), (b) and (c) illustrate the same guide plate from different angles,

so that (a) illustrates the situation when viewed in the direction of the feed screw 1, (b) illustrates the situation when viewed from the side of the feed screw, and (c) illustrates the situation when viewed from the top of the feed screw. According to Figure 5, the guide plate is in the area of said vertical channel inclined in the vertical direction of the earlier defined vertical plane, whereas below the troweling beam the guide plate is inclined in the horizontal direction of the defined vertical plane. Preferably the guide element is inclined at an angle of 0 - 5° with respect to the vertical plane passing via the center axis of the feed screw, and at largest the angle can be about 30°. With respect to the plane passing via the front edge of the troweling beam, the inclination can also be of the same degree as was mentioned above (Figure 4 (c)). By means of guide elements placed at a defined angle, the progress of the concrete mix can be guided in the desired direction.

**[0032]** As is apparent from the discussion above, part of several different guide elements 4 placed above one and the same feed screw 1 can be inclined in different directions, in different ways, and part can be placed in parallel with the defined vertical plane. Various different combinations are possible, and the appropriate structure and shape of the guide element or elements can be defined separately in each case.

**[0033]** According to a particular embodiment, when the slipform casting equipment comprises more than one feed screw 1, said at least one guide element 4 is placed in a different way above each different feed screw 1. In other words, at least one set of guide elements 4 of feed screws 1 located at the edges can be different and/or inclined in a different way than at least one set of guide elements 4 of feed screw or screws 1 located in the middle. Thus the feeding of concrete mix can be efficiently balanced in the transversal direction of the slipform casting equipment. According to the invention, it is also possible, when the slipform casting equipment comprises at least two feed screws 1, that said at least one guide element 4 is not placed above every feed screw. The essential feature is that at least one feed screw 1 comprises at least one guide element 4 placed above the screw.

**[0034]** According to yet another embodiment of the invention, the top troweling beam is designed to conform to the shape of the screw, both in the longitudinal and in the transversal direction. This design can be realized either by a separate guide element attached to the troweling beam, or the troweling beam itself is shaped appropriately. In this embodiment, the extension of the element 4 in the area of the orifice of the concrete mix container must be optimized, so that it does not disturb the flowing of the mix from the concrete mix container 5, but it causes an optimal distribution of the concrete mix on the top and bottom surfaces of the product to be cast.

**[0035]** According to the present invention, the shape and structure of the guide element 4 can be designed and measured individually for each application of usage.

**[0036]** From the point of view of the invention, it is es-

sential that the concrete mix is guided in a balanced way, so that the mix flow is evenly distributed on the top and bottom surfaces of the product to be cast, in the longitudinal direction of the whole product. This is partly due to the fact that the component of the mix speed vector that is transversal to the casting direction, i.e. the rotary motion of the mix along with the screw, is minimized also above the feed screw.

## Claims

1. A slipform casting apparatus comprising at least one feed screw (1) and at least one guide element (4) for balancing the supply of concrete mix between the top and bottom surfaces of the concrete product to be cast, in which apparatus said at least one guide element (4) is attached to a troweling beam (3), **characterized in that** the at least one guide element (4) is placed at and above said feed screw (1), so that in the longitudinal direction of the slipform casting apparatus, said at least one element (4) extends substantially from the halfway of the vertical channel formed by a mass plate (10) and the troweling beam (3) substantially to the end of the threaded part of said feed screw (1), and in the vertical direction, said at least one element (4) extends, from the troweling beam and in the area of said vertical channel, from the height of no more than 300 mm above the surface (11) of the troweling beam, substantially to the immediate vicinity of the threadings of said feed screw, along the whole length of said guide element (4).
2. A slipform casting apparatus according to claim 1, comprising at least two guide elements (4) placed above said feed screw (1).
3. A slipform casting apparatus according to claim 1, comprising three guide elements (4) placed above said feed screw (1).
4. A slipform casting apparatus according to any of the preceding claims, where said at least one guide element is a guide plate (4a/4b).
5. A slipform casting apparatus according to claim 4, where the lower edge of the guide plate (4a/4b) is provided with cogs.
6. A slipform casting apparatus according to claim 4, where at least one of the side walls of the guide plate (4a/4b) is provided with cogs.
7. A slipform casting apparatus according to any of the preceding claims, where said at least one guide element (4) extends in the vertical direction, in the area of said vertical channel, for the height of 50 - 200 mm, and preferably for the height of 100 - 150 mm

above the surface (11) of the troweling beam.

8. A slipform casting apparatus according to any of the preceding claims, where said guide element (4) extends in the vertical direction for the distance of 0 - 50 mm, preferably for the distance of 1 - 20 mm of the threadings of the feed screw.
9. A slipform casting apparatus according to any of the preceding claims, where said at least one guide element (4) is substantially parallel with the vertical plane passing in the direction of the center axis of the feed screw (1).
10. A slipform casting apparatus according to any of the claims 1 - 8, where said at least one guide element (4) is inclined with respect to a vertical plane passing in the direction of the center axis of the feed screw (1).
11. A method for casting a concrete product with a slipform casting apparatus, said concrete product having a top surface and a bottom surface, said method comprising the following steps:
  - a) concrete mix is fed from a concrete mix container (5) under hydrostatic pressure to at least one feed screw (1);
  - b) said concrete mix is extruded in a mold defined by a casting bed (9), side walls (8) and a top troweling beam (3), by means of a rotary and reciprocating motion of said at least one feed screw (1),**characterized in that** the method also includes the following step:
  - c) the supply of said concrete mix is balanced by means of at least one guide element (4) attached to the troweling beam (3) above said at least one feed screw (1).

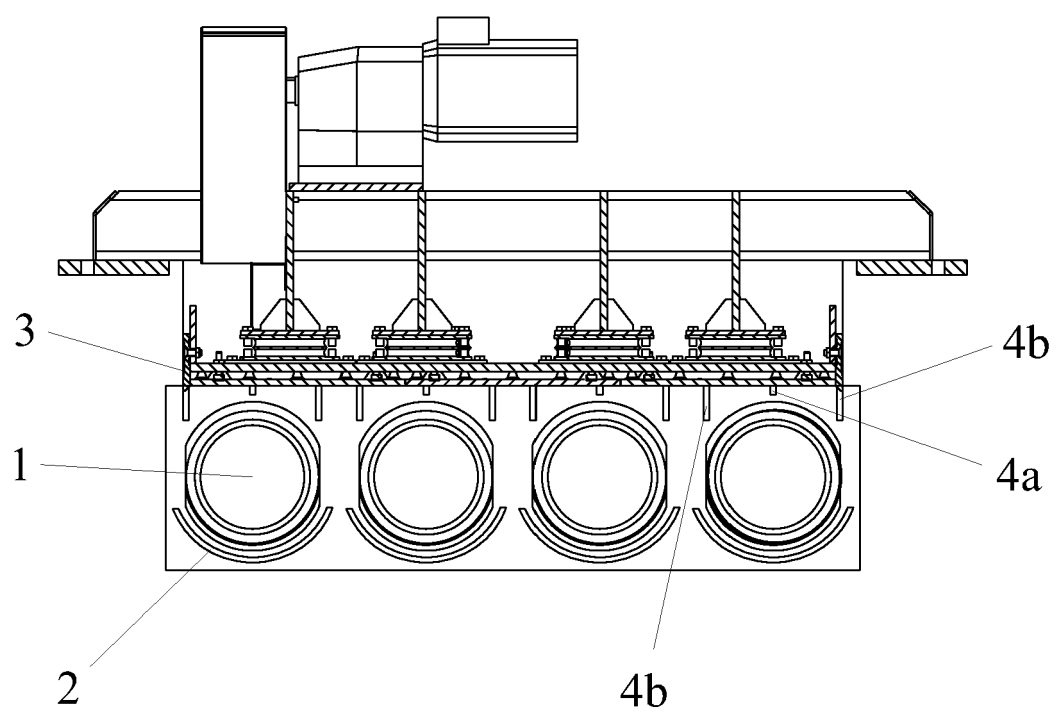


FIG. 1

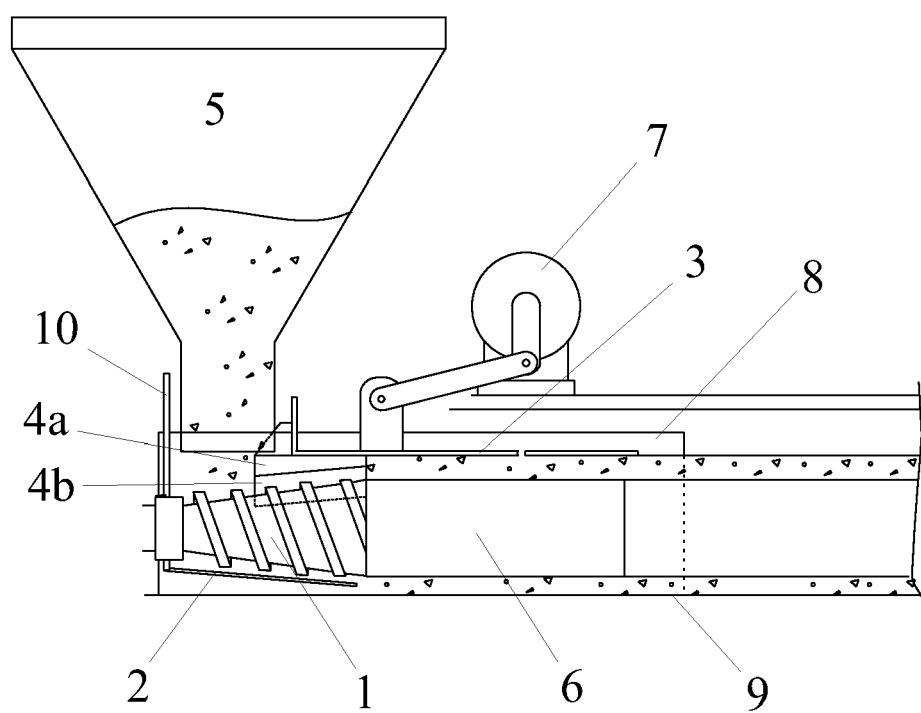


FIG. 2

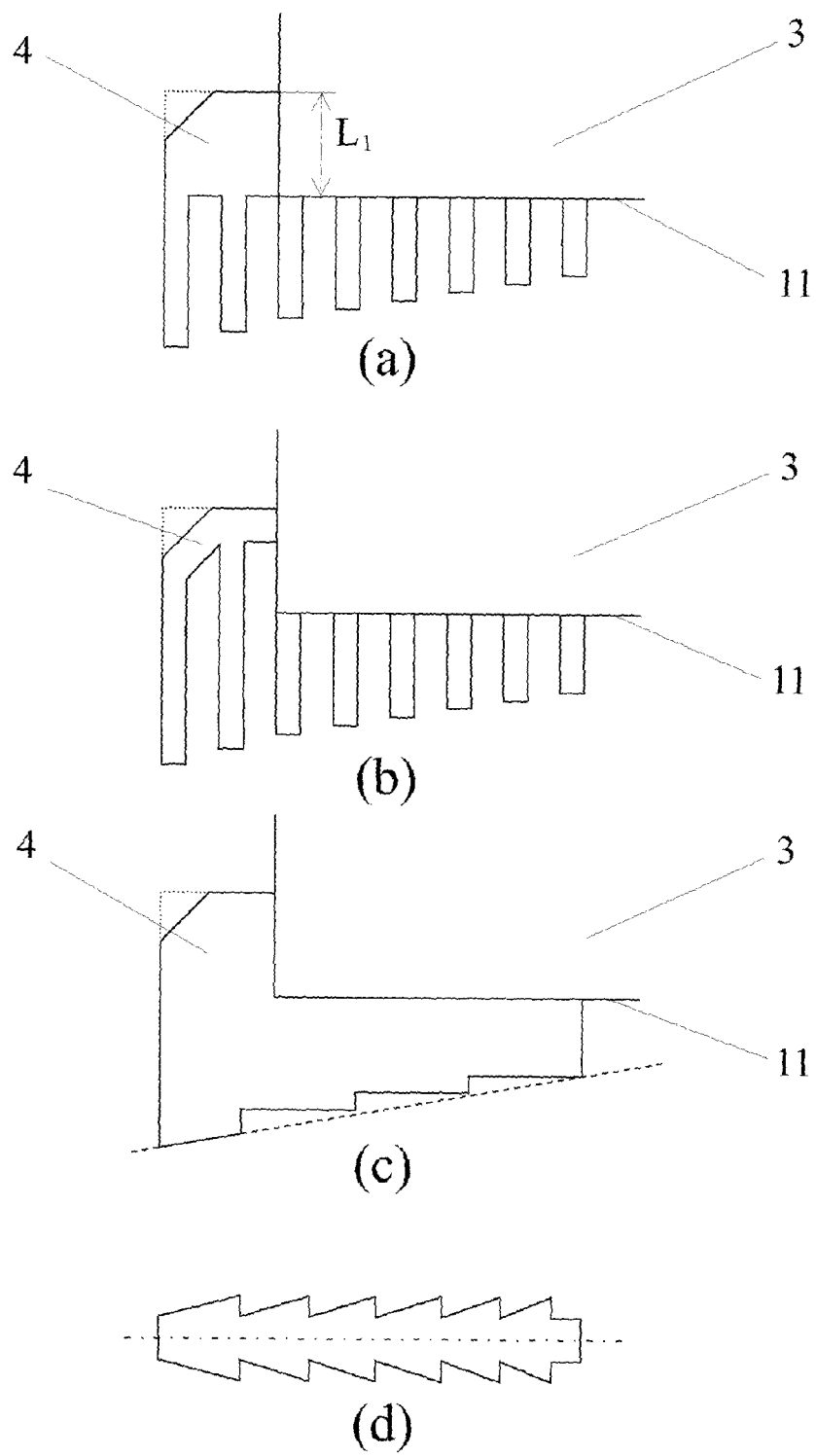


FIG. 3

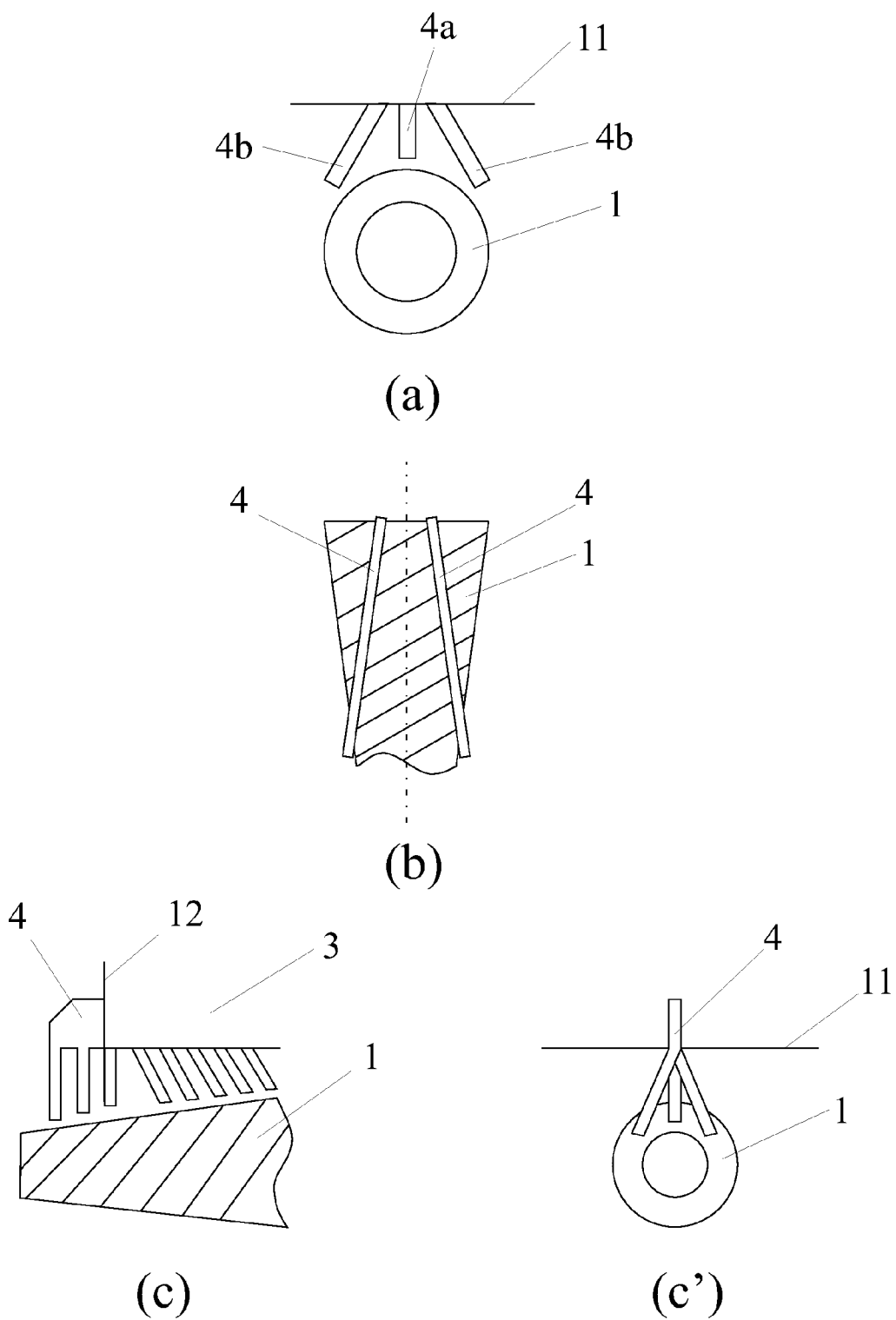


FIG. 4

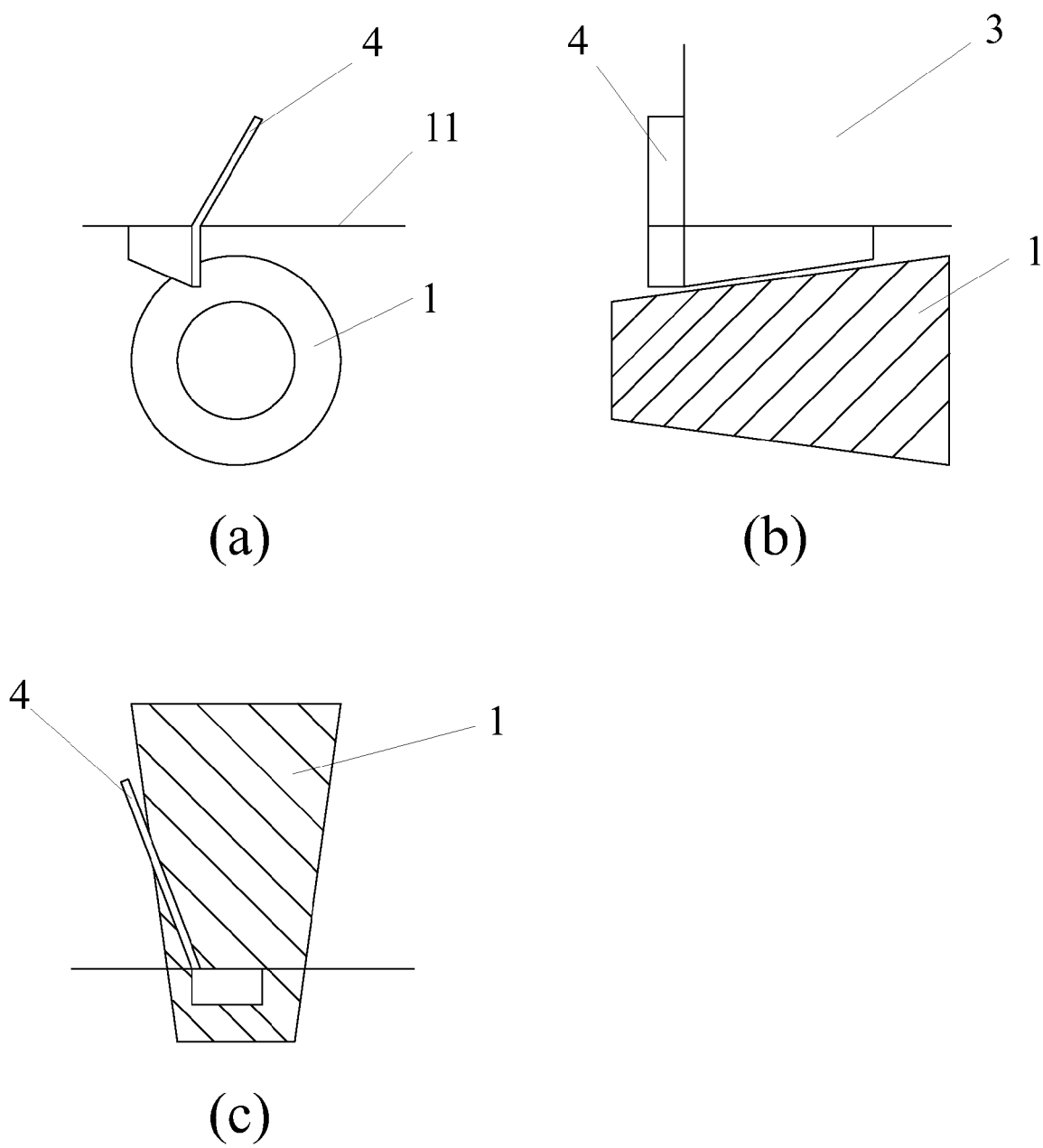


FIG. 5

**REFERENCES CITED IN THE DESCRIPTION**

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