Title: CONCRETE PRODUCT AND METHOD AND APPARATUS FOR PRODUCING A CONCRETE PRODUCT

Abstract: The invention relates to a method and apparatus for manufacturing a fiber-reinforced concrete product, in which method at least one auger feeder (5) is used for propelling concrete mix through a defined extruder cross section (20, 21, 23). In the manufacture of the product, at least two different materials are produced suitable for use in the manufacture of a concrete product, at least one of the materials containing reinforcing fiber and both materials being dosed onto the auger feeders (5). The apparatus has two containers for the materials and during the feeding the relative proportions of the materials are controlled so that the ratio of the amount of the fiber-reinforced material to the amount of the unreinforced material is such that gives the end product an inhomogeneous distribution of the reinforcing fiber in the volume of the product, whereby at least one portion of the product volume has a greater volumetric content of the reinforcement than that of an equivalent volume in at least one other portion of the product. The final cast product contains desired amounts of reinforcement on areas where bigger loads are to be imposed on the product.
Concrete product and method and apparatus for producing a concrete product

The invention relates to a method according to the preamble of claim 1 for manufacturing a concrete product by means of an extrusion technique. The invention also relates to an extruder-type casting apparatus suited for implementing the method according to the invention.

Cast concrete products such as hollow-core slabs, piles or solid-core slabs can be made using an extruder-type casting technique. Hollow-core slabs or the like load-bearing structures subjected to tensile stresses are reinforced by longitudinal reinforcing steel bars or prestressing steel wire strands. The use of crosswise placed steel inserts as well as other reinforcing steels in the form of conventional inserts or wire mesh is so complicated to arrange in mass production that the use of such reinforcement steel fabrics is not possible due to technical and economical restraints. Resultingly, slabs find limited applications within the regulations of normal building codes and as to their static and dynamic load-bearing capability and resistance under fire situations. These limitations are accentuated in broad slabs, at the edges of large openings and when the slab is subjected to large point or lineal loads. The same limitations are partially true for products manufactured using other slip-casting methods, too.

In certain specific cases, the element may be cast from a concrete mix having reinforcing fiber such as steel fiber
added thereto for the purpose of allowing the building component such as a hollow-core slab to be used under normal code regulations with due attention paid to the function of the building component under static and dynamic loads and in fire situations. However, even these reinforced building components produced in the form of, e.g., slabs find limited use, because of the cost increase of the concrete due to the added reinforcement material, which makes the use of thus reinforced products justified in particularly demanding applications only, wherein the performance of the more expensive product can be utilized to a sufficiently high degree. Steel fiber is easy to add into the concrete mix used and such fiber is the most preferred choice by its function and cost. However, current slip-casting methods are suited for the manufacture of products in which one or maximally not more than two different casting mixes are used. For instance, continuous-casting apparatuses allow the concrete mix portion of the underside of the product to be applied first on the casting bed, whereupon the rest of the concrete mix is applied onto the underlying layer of concrete. In this fashion, it is possible to use different kinds of concrete mixes superimposed in the vertical direction of the product within the limitations that the thickness of the concrete forming the underside layer must be made thin, at least in the manufacture of hollow-core slabs, and there is no possibility of varying the layer thickness. In extruder-type casting apparatuses, feed of two different types of concrete mixes has not been implemented in the art due to the problems caused by the substantial impact of the pressure imposed by the auger feeders on the compaction of the casting mix.
Should a portion of the concrete mix be fed directly onto
the casting bed from below the auger feeders, there
arises a risk of inferior compaction in the underside
layer of the cast product.

It is an object of the present invention to provide a
method and an apparatus for the manufacture of fiber-
reinforced concrete products by means of extruder tech-
niques and a concrete product having its fiber reinforce-
ment so divided in given portions of the product that the
different portions of the product can be made to possess
varying strength qualities.

The goal of the invention is achieved by means of distri-
buting the fiber reinforcement in an inhomogeneous
fashion within the volume of the product so that at least
one portion of the product volume has a greater volumet-
ric content of the reinforcement than that of an
equivalent volume in at least one other portion of the
product.

According to one feature of the invention, at least two
feeder containers are used in the manufacture of the
concrete product. Herein, one container is filled with a
normal concrete mix and the other with fiber-reinforced
concrete mix. By way of varying the feed ratio of these
two mixes, it is possible to control the fiber density in
the different portions of the component being
manufactured. Resultingly, the fiber-containing mix may
be extruded via the auger into different portions of the
cast product so that the fiber content of each portion
reaches a desired level.
More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the apparatus according to the invention is characterized by what is stated in the characterizing part of claim 11.

The product according to the invention is characterized by what is stated in the characterizing part of claim 17.

The invention provides significant benefits.

By virtue of the method according to the invention, the fiber reinforcement can be dosed in desired amounts into a desired portion of a component, thus placing the reinforcement in the most appropriate locations. The addition of fiber reinforcement can be employed to increase, e.g., the spectrum of applications, competitive edge and technical performance of prestressed hollow-core slabs. By way of locating the reinforcement only at points of the building component subjected to a higher or different type of loading than the other portions of the component, a lesser quantity of fiber reinforcement will be sufficient to produce a building component having the same strength as that possessed by prior-art products. The structure of the manufactured components may also be lightweighted, thus expanding the range of their applications. The static and dynamic load-bearing capability of hollow-core slabs made using the method according to the invention is improved, which means that among others such
qualities as their loading capacity and resistance under vibration and movement is improved thus rendering them a superior performance under seismic conditions. The slabs may also be subjected to larger lateral loads. When added to the slab ends, the fiber reinforcement reduces cracking of the slabs and improves their shear strength. Additional fiber reinforcement at the lateral sides of the slabs increases their strength under lifting and torsional loads. When applied at the edges of slab openings, the reinforcement improves the overall load-bearing capability of slabs, while addition of fiber reinforcement to the isthmuses remaining between the hollow spaces of the slab core can give the slab a higher shear strength and reinforcement at the bottom of the slab reduces cracking of slabs. Respectively, addition of reinforcement to the top wall of large hollow spaces in the slab helps keep the cast product in shape during casting. Ram piles manufactured using the method according to the invention can be reinforced at their top ends resistant to the blows of the ram. When necessary, slabs or other similar products may be manufactured even in singular quantities with individually placed reinforcements according to the loading situation in the target application. By virtue of the invention, it is possible to use different types of dimensioning rules and structural designs, since there is no more any need for designing the entire slab according to the peak load occurring within a limited area.

The invention is next examined with the help of the exemplifying embodiments illustrated in the appended drawings, in which
FIG. 1 shows a side view of an embodiment of an apparatus according to the invention suited for the manufacture of three concrete piles;

FIG. 2 shows a front view of the apparatus illustrated in FIG. 1;

FIG. 3 shows a cross-sectional view of a hollow-core slab manufactured according to the invention;

FIG. 4 shows a perspective view combined with a cross-sectional view of another embodiment of a hollow-core slab manufactured according to the invention; and

FIG. 5 shows a cross-sectional view of a third embodiment of a hollow-core slab manufactured according to the invention.

Referring to FIG. 1, therein is shown an apparatus for manufacturing three concrete piles. The apparatus comprises a metallic framework 7 having adapted thereto a conical hopper container 8 in which the top and the bottom are open. A partition 12 divides the hopper container 8 in two compartments, named a basic mix container 1 and a reinforcement material container 2, wherein also the top and bottom parts of the hopper container 8 are respectively partitioned in two compartments. Depending on the desired feed proportions of the materials, the volumetric ratio of the reinforcement material container 2 to the basic mix container 1 can be selected to be, e.g., 1:3. Into the interior of the reinforcing material
container 2 is mounted a feeder means 4. The feeder means 4 comprises a wide toothed gear 9, a drive shaft 10 of the toothed gear adapted to penetrate the container wall and a drive motor not shown in the diagram serving to rotate the drive shaft 10 from the exterior side of the container. To the lower edge of the partition 12 is hingedly mounted a control vane 3 by means of which the cross-sectional ratio between the bottom openings of the hopper container compartments can be adjusted. The size of the control vane 3 is dimensioned so that if necessary the vane 3 can entirely shut off the exit openings at the bottom corner of either one of the container compartments 1, 2 so that the angle of the control vane 3 relative to a vertical plumb line does not exceed a given angle (e.g., an angle not greater than 40°), thus avoiding the hinges of the vane from becoming subjected to an excessive stress under the weight of the overlying concrete mix. A tube 19 is adapted to the lower part of the container, under the control vane 3. The lower portion of the tube 19 is aligned to fit into an opening made to the framework 7. Three auger feeders 5 with their infeed ends coinciding with the overlying outlet end of the tube are mounted in a horizontal position to the interior of the framework. The framework 7 has solid walls at its both sides facing the auger feeders. Each auger feeder 5 with its one supported by the framework 7 and the other end terminating at a core-forming member 6 is rotatably mounted on bearings. Approximately at the level of the lower edges of the auger feeders 5, the wall of the framework 7 on which the augers are mounted on bearings is provided with openings via which reinforcing bars can be introduced into the cast mix. Below the auger
feeders 5 are mounted the concrete mix feed troughs 24 that pass the concrete mix further toward the extruder section.

In the manufacture of concrete products, the extruder section of this type of apparatus operates in the same fashion as a conventional extruder-type casting apparatus, wherein the auger feeders 5 extrude the concrete mix through the extruder section which is defined from above by a top wall 20 of the casting apparatus framework and, in the cross-machine direction, by side and intermediate walls 21 that serve to laterally compartmentalize the extruder section and, finally, by the core-forming members 6. During this passage, the concrete mix is compacted and worked in the extruder section interior space 20, 21, 6 under the pressure exerted by the auger feeders 5 and the movement of a compacting device 22 mounted on the top wall 20. The auger feeders 5 are arranged to propel concrete mix into the spaces formed between the core-forming members 6 and the walls 20, 21 of the extruder section. The extruder section is defined so that the concrete mix propelled therethrough is forced to form three objects of a square external cross section and a cylindrical hollow core defined by the core-forming member 6. The undercarriage portion of the framework 7 is provided with axles 13 and 14, each one of them having two wheels mounted thereon so that the axle 13 is running on wheels 15 and 16, while the axle 14 is running on wheels 17 and 18, respectively. Supported on the wheels, the entire apparatus moves on the casting bed under the propelling force exerted by the auger feeders.
The apparatus shown in FIG. 1 is suited for the manufacture of ram piles by virtue of the method described below. First, a basic concrete mix and a batch of steel fiber are prepared. Next, the reinforcing steel fiber is mixed with a portion of the prepared concrete mix. The unreinforced portion of the mix called gray concrete is poured into the basic mix container 1, while the fiber-reinforced portion is filled into the reinforcement material container 2. If necessary, the feeder means 4 is rotated to ensure unproblematic feed of the stiff fiber-reinforced portion from the reinforcement material container 2 forward into the extruder section. The ratio of the cross-sectional area of the bottom openings of the basic mix container 1 and the reinforcement material container 2 is controlled by adjusting the position of the control vane 3. The surface area ratio between the bottom openings of the container compartments determines the feed ratio between the different concrete mixes passing from both sides of the control vane and, hence, the amount of fiber reinforcement, as a function of the length or casting time of products being cast, in the blended mix passing forward in the system. Thus, the feed ratio of the different materials being cast can be selected to be controlled by a function related to the time or instantaneous position of the casting apparatus travel. From the control vane 3, the blended concrete mix is poured along a cylindrical tube 19 through an opening of a horizontal cross section into the space surrounding the auger feeders 5, wherefrom the auger feeders propel the mix through the extruder section. Longitudinal reinforcing steel bars are introduced into the mix being cast via openings made to the framework 7 about the
bearing blocks of the augers 5 at the height of the auger feeders 5. The entire apparatus moves in synchronism with the continuous casting of the worked concrete mix, and the extruded mix can be allowed to cure on the casting bed 23.

The above-described apparatus is suited for the manufacture of such products in which the proportion of the reinforced concrete mix is varied in the longitudinal or vertical direction of the finished product. As the auger feeders do not actually agitate the concrete mix, but rather, propel it forward, a proportionally greater amount of the unreinforced gray concrete being fed to the rear of the auger feeders travels guided by the auger feed trough 24 to the space of the extruder section underlying the augers. Hence, the angular position of the control vane 3 determines the proportion of reinforced material in the mix being fed and the entry point of the same on the augers 5. If the vane 3 is rotated toward the discharge opening of container 2, the amount of mix fed therefrom is reduced, whereby the amount of fiber-reinforced or unreinforced concrete as a function of the vertical direction of the product cross section is changed. When either one of the discharge openings is fully closed, the product cross section will contain only the concrete mix poured from the other opening. Hence, by way of selecting the container into which the fiber-reinforced concrete mix is initially loaded, it is possible to select whether the reinforced concrete will be added in the above-described process to the underside or the top side of the product being cast.
In FIGS. 3 - 5 are shown three different principles of dividing the addition of fiber reinforcement via the extruder section into the product. The product illustrated in FIG. 3 has the fiber-reinforced concrete fed to the lower portion 25 of the slab so that the reinforced concrete effectively reaches up to the isthmuses 26 in the cross section of the hollow core spaces. This arrangement allows the load-bearing capacity of the slab to be increased, e.g., in cover structures and other applications where the slab is supported by its ends. The slab illustrated in FIG. 4 with the reinforced concrete placed zone-wise over the length of the slab is suited for use in applications in which a limited area is stressed by a load such as a lineal load acting in a defined manner. This category includes such applications as, e.g., structures designed to support a load-bearing wall or constructions placed under conveyors or tracks. In the slab shown in FIG. 5, the reinforcement is concentrated at the lateral sides of the slab, thus rendering the side areas a good compressive load resistance and shear strength. The illustrated slab is also strengthened by cross-wise placed reinforcement steels. As the above-described examples represent a few embodiments of a product manufactured according to the invention, their reinforcement addition techniques serve as starting points for the combinations thereof. Obviously, it is also possible to modulate the feed rate of the reinforced concrete or the reinforcing material, respectively, so that the amount of the reinforcing material varies, e.g., in the vertical or lateral direction along the length of the slab. Accordingly, it is possible to manufacture a
slab having the reinforcement placed in the entire cross section of the slab at its ends, while the center of the slab is reinforced only at its bottom or lateral sides.

In FIG. 6 is shown an apparatus suited for improved distribution of the concrete mixes to the different portions of the slab in its vertical direction. Herein, the discharge tube of the concrete mix feed hopper 8 is provided with a movable baffle 30 having its lower edge extending close to the upper level of the augers 5. With the help of this baffle, it is easy to control the discharge point of the fiber-reinforced concrete mix into the auger feed trough 24 and, hence, in the vertical direction of the cross section of the cast product. If the lower edge of the baffle 30 is rotated close to the start of the auger flight, the reinforced concrete is effectively guided by the feed trough to the bottom portion of the cast product. In contrast, rotation of the baffle 30 closer to the core-forming member 6 increases the proportion of the gray concrete fed from the container 1 in the product cross section. In this embodiment, both container compartments are equipped with separate closing means 31, 32 in order to provide independent feed rate control for either type of concrete mix.

In addition to those described above, the present invention may have alternative embodiments.

For instance, the apparatus according to the invention can be provided with feed nozzles of the fiber-reinforced concrete mix that are located at different points in the longitudinal, lateral and height directions of the feed
nozzle area. The concrete mix can be forced through the nozzles with the help of auger feeders or pumps. In the use of this type of apparatus, the reinforcing fibers are mixed in substantial quantities in a bonding agent such as slurried cement, and the feed rate of the reinforcing material through the nozzles can be controlled by manual or electronic means as a function of casting time on the basis of product data retrieved from a database. Also the rotation speed of the augers is made adjustable as a function of casting time. Furthermore, the apparatus according to the invention shown in FIG. 1 may be modified so that the control vane 3 is divided into at least two separately hinged parts, whereby the content of fiber reinforcement in the product being cast can be adjusted in both the longitudinal and lateral direction of the product. It may be further contemplated that the concrete mix feed is arranged to take place from a system such as a container or a concrete mixing machinery separate from the extruder apparatus via piping to the extruder apparatus. A disadvantage of this arrangement is, however, that at the end of a run there will remain a large amount of concrete in the piping, particularly on production lines adapted for the manufacture of long products.

Instead of the vanes used in the above-described embodiments, the closing devices adapted to the separate compartments and concrete mix feeder means may obviously be of any other type, e.g., sliding gates or expandable closing bellows made from a flexible material. The concrete mix feed tube 19 connected to the containers may be designed into a changeable nozzle tube assembly having passageways or channels for concrete feed into a desired
point in a longitudinal or lateral direction along the product being cast. This kind of a nozzle assembly could be provided with a number of separate concrete feed lines passed from the hopper container to the discharge opening located above the auger feeders. By virtue of the changeable nozzle assembly, the apparatus can be adapted more readily for the manufacture of different kinds of products. The invention also makes it possible to design apparatuses equipped with core-forming members of varied shapes that permit the manufacture of lightweight structures having respectively varied hollow-core shapes. The method according to the invention is also suited for the manufacture of such products that are made using a greater number of different concrete mixes than the above-mentioned fiber-reinforced concrete mix and the unreinforced gray concrete mix conventionally used in standard products. Instead of steel fiber, the reinforcing material may be selected from the group of other suitable materials such as synthetic fiber, glass fiber and metallic fiber of a non-steel variety. The advantageous price, good strength and the thermal expansion coefficient matching that of concrete, however, give steel fiber a preference as the most cost-efficient reinforcement material. When desired, the fiber reinforcement may be blended in the basic concrete mix among other additives such as slurried cement.
What is claimed is:

1. Method for manufacturing a fiber-reinforced concrete product, in which method at least one auger feeder (5) is used for propelling concrete mix through a defined extruder cross section (20, 21, 23), characterized in that

- at least two different materials are produced for use in the manufacture of a concrete product, at least one of the materials containing reinforcing fiber,

- both materials are dosed into the auger feeders (5), and

- the relative proportions of said materials are controlled so that the ratio of the amount of the fiber-reinforced material to the amount of the unreinforced material is such that it gives the end product an inhomogeneous distribution of the reinforcing fiber in the volume of the product, whereby at least one portion of the product volume has a greater volumetric content of the reinforcement than that of an equivalent volume in at least one other portion of the product.

2. Method according to claim 1, characterized in that the proportion of the amount of fiber-reinforced material is varied as a function of time or position of the extruder-type casting apparatus.
3. Method according to claim 1 or 2, characterized in that the amount of fiber-reinforced material is controlled so that the material feed consists of the fiber-reinforced material alone to at least the end portions of the product being cast.

4. Method according to claim 1 or 2, characterized in that the amount of fiber-reinforced material is controlled so that the material feed consists of the fiber-reinforced material alone to at least the lateral side portions of the product being cast.

5. Method according to claim 1 or 2, characterized in that the amount of fiber-reinforced material is controlled so that the material feed consists of the fiber-reinforced material alone to at least the bottom portion of the product being cast.

6. Method according to any one of claims 3 - 5, characterized in that at least one prestressing steel bar is inserted into the product during its casting.

7. Method according to any one of claims 3 - 5, characterized in that into said defined extruder cross section is placed at least one core-forming member (6) for the purpose of making a hollow-core space in the product being cast.

8. Method according to claim 1 or 2, characterized in that into said defined extruder cross
section is placed at least two core-forming members (6) for the purpose of making hollow-core spaces in the product being cast and for feeding the fiber-reinforced material into at least a portion of the solid material volume remaining between said hollow-core spaces.

9. Method according to claim 1, characterized in that the fiber reinforcement is first blended with an additive material and then introduced therewith into the cast.

10. Method according to claim 1, characterized in that the fiber reinforcement is first blended with a concrete mix and then introduced therewith into the cast.

11. Apparatus for manufacturing a fiber-reinforced concrete product, the apparatus comprising

- elements (20, 21, 23) for forming a defined cross section,

- at least one auger feeder (5) for propelling concrete mix through said defined cross section in order to form a concrete product, and

- means (1, 2, 19) for feeding concrete mix on said auger feeders (5),

characterized in that said means for feeding concrete mix comprise
- means (2, 19) for feeding at least a concrete mix,

- means (1, 19) for feeding at least one material used in the manufacture of said concrete product, and

- means for controlling the relative feed proportions of the concrete mix and the other materials so that the ratio of the amount of the fiber-reinforced material to the amount of the unreinforced material is such that gives the end product an inhomogeneous distribution of the reinforcing fiber in the volume of the product, whereby at least one portion of the product volume has a greater volumetric content of the reinforcement than that of an equivalent volume in at least one other portion of the product.

12. Apparatus according to claim 11, characterized in that said means for feeding the casting materials include two containers (1, 2) for feeding different types of concrete mixes and means (3) for altering the feed ratio of said casting materials.

13. Apparatus according to claim 11, characterized in that said means for feeding the casting materials include a nozzle tube divided in at least two separate feed channels for the purpose of feeding different types of concrete mixes onto said auger feeders (5).
14. Apparatus according to claim 11, characterized in that said means for feeding the casting materials include at least one feed nozzle for feeding a fiber-reinforcement-containing additive into the flow of the casting material.

15. Apparatus according to claim 11, characterized by means for feeding fiber-reinforced material to the lateral side portions of the product being cast.

16. Apparatus according to claim 11, characterized by means for feeding fiber-reinforced material to the underside portions (24, 30) of the product being cast.

17. Concrete product consisting of at least one type of concrete mix and at least one type of fiber-reinforced material, characterized in that the ratio of the amount of the fiber-reinforced material to the amount of the unreinforced material is such that gives the end product an inhomogeneous distribution of the reinforcing fiber in the volume of the product, whereby at least one portion of the product volume has a greater volumetric content of the reinforcement than that of an equivalent volume in at least one other portion of the product.

18. Product according to claim 17, characterized in that the cast product contains the fiber-reinforced material at least in its end portions.
19. Product according to claim 17, characterized in that the cast product contains the fiber-reinforced material at least in its underside portions.

20. Product according to claim 17, characterized in that the cast product contains the fiber-reinforced material at least in its lateral side portions.

21. Product according to claim 17, characterized in that the fiber-reinforced material is distributed in the longitudinal direction along the length of the cast product in segments alternating with those of unreinforced material.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00458

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B28B 1/52, B28B 3/22, E04C 2/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B28B, E04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WIP, EPDOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search

30 August 2000

Date of mailing of the international search report

07-09-2000

Name and mailing address of the ISA

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