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(54) Method and apparatus for producing a concrete product.

(57) The present invention relates to a method and apparatus for producing a concrete product in an extruder casting machine, continuous-casting machine or similar equipment. The concrete mix is fed in a conventional manner through a space of delineated cross section, where the continuous-section product is given its desired shape. The concrete mix being cast is compacted during the casting process to the end of removing entrapped air and achieving a constant casting quality of the product. According to the invention, at least one of the compaction movements is a direction-controlled reciprocating compaction movement having at least one translational component in the direction of the casting flow of concrete and at least one translational component perpendicular to said at least one first translational component.

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The present invention relates to a method according to the preamble of claim 1 for producing a concrete product using an extruder casting machine, a continuous-casting machine or similar equipment.

The invention also concerns a casting machine according to the preamble of claim 7 suited for implementing the method.

Elongated concrete products such as hollow-core slabs are conventionally produced using extruder-type casting machines, or alternatively, continuous-casting machines. The casting machine is comprised of a conical feed hopper connected to one or more feed augers beneath. The feed auger is frequently followed by a core-forming mandrel which is further extended as an auxiliary mandrel supporting the core cavity formed within the product. The core-forming mandrel incorporates a vibrator or similar compacting arrangement for the compaction of the cast concrete into the shape determined by the casting mould and the mandrels. Furthermore, the casting machine has an upper trowelling beam forming the upper edge of the mould, and frequently, the sides of the mould are also designed to perform as side trowelling beams. The trowelling beams compact the concrete mix during the course of the casting process and give the cast product a neat surface finish. In addition to trowelling or augmentation thereof, vibration can also be employed for compaction. Extruder-type casting machines are designed to operate as continuous-casting machines, which are transferred forward on the mould top by the reaction forces imposed by the feed augers.

Extruder-type casting machines have undergone a continuing development for a relatively long time, and the first extruder casting machines were developed at the end of the 1960's. Initially, the function of extruder casting machines was based on conventional vibrating techniques in which the compaction of concrete is achieved by virtue of different modes of vibration. By means of vibration, the flow of concrete is also essentially eased in the machine. The function of vibration is to impart the concrete aggregates such a high speed that the collision impulse between the particles can reach a sufficiently high energy level to augment the shifting of the aggregate particles and thus the compaction of concrete. The vibrating frequency has typically been in the order of 12.5 - 200 Hz and suitable vibrating equipment is available from several manufacturers. Inventions related to extruder casting machines in the prior art are based on the use of a standard type of vibrator and, obviously, dedicated types of machine constructions. The vibrator equipment typically employed is a rotating vibrator in which a rotating eccentric mass makes a body attached to the vibrator to perform a movement in the same direction the mass and dependent on the rotational speed of the eccentric mass, and this movement is further transferred to the concrete mix. Extruder casting machines have vibrators mounted on different sides of the machine, and the concrete mix is desiredly subjected to efficient compaction particularly in the forming and compacting zone of the concrete product. Typically, vibrators have been used in at least core-forming mandrels which with their vibration in the concrete mix achieve efficient compaction of concrete in all directions perpendicular to the flow of concrete particularly in the formation zone of the cast product.

Instead of vibration, compaction has also been achieved by relatively slow movements of the different parts of the casting machine that work the concrete mix. Such compacting movement has been implemented by means of either a sideways deflected rotational movement of the core-forming mandrel which follows the auger and/or cyclic deformation of said mandrel, whereby the compaction of the concrete surrounding the mandrel is attained through varying the cross section of the mandrel. The cyclic reciprocating rotational movement has been used particularly for compaction in conjunction with mandrels of noncircular cross section. All of these machines have been characterized in that the compaction of concrete has been achieved by means of mechanical movements at a low frequency, whereby the movement of aggregate particles relative to each other results from the pushing forces caused by the movement of the machine components, not by the impact of the aggregate particles on each other.

In the art the above-described compacting method is generally called the working compaction or the shear compaction, and one of its benefits is that the movements and displacements of aggregate particles will be large already at low number of movements, that is, at low frequency, resulting in noiseless operation of the machine.

The principle of low-frequency compacting movements has been further developed in an apparatus in which the core-forming mandrels are provided with conical or wedge-shaped surfaces, whereby concrete is compacted by means of slow longitudinal movements of the mandrels. In practice, the compaction is performed using reciprocating movement with an amplitude of 5 - 50 mm and a frequency of 1 - 10 Hz, which are slow relative to the amplitudes and frequencies used in vibrating. To improve the compacting friction, the machine uses wedge-shaped or conical mandrel surfaces which provide flaring or tapering spaces in the direction of the casting flow, said spaces acting as compacting spaces.

Conventional embodiments of vibrating technology have several shortcomings, while some of them may achieve relatively good compaction. As mentioned above, their greatest drawback has been noisy operation caused by the high-frequency vibration itself and the nonoptimal location of the vibrating equipment on the different structures of the casting machine, and in particular, the almost random direction of the vibrating force which typically is perpendicularly oriented with the casting direction and the machine structure. Such uncontrolled vibrating force is more imposed on the machine than the concrete mix itself thus causing a strong stress on the machine structures. Another disadvantage of the cross-machine vibrating scheme has been the impeded flow of concrete through the machine which causes unnecessary increase of pressure inside the machine and strong wear of machine components. While shear-compacting types of casting machines achieve a lower level of noise emission, they have other shortcomings related to the machine construction, operation and casting result.

The constructions of shear-compacting casting machines become somewhat more complicated than those of vibrating casting machines, and due to the long shearing strokes required, it is necessary to use sliding surfaces which are difficult to seal, whereby the flowing concrete mix causes wear and damage at these points of the machine. Mere low-frequency compaction principally works on large aggregate particles alone, whereby small particles remain uncompacted meaning that small aggregates will not be displaced to a new and better position in the aggregate matrix and the removal of small entrapped gas bubbles from the concrete mix will be poor. This problem is particularly strongly accentuated with the modern, so-called micro-proportionated concrete mixes, which in the conventional casting methods fail to achieve their potentially highest strength, and moreover, remain unsatisfactorily compacted.

It is an object of the present invention to achieve a method and an apparatus capable of achieving improved and faster compaction over the prior art particularly in the production of high-strength concretes.

The invention is based on implementing the compaction of concrete using at least one direction-controlled compacting movement having simultaneously one directional vector component parallel to the flow of the concrete mix and one directional vector component transverse to the flow of the concrete mix.

According to a preferred embodiment of the invention, the concrete mix to be moulded is subjected to at least one second compacting movement with a frequency different from that of a first dual-direction-controlled compacting movement.

More specifically, the method according to the invention is principally 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 7.

The invention provides significant benefits.

Compaction is advantageously performed using a number of different vibrating frequencies, and particularly, complementing the mechanical low-frequency compacting movement with a number of higher-frequency vibrations, whereby the compacting effect is imposed on aggregate particles of all sizes. When this basic scheme is combined with direction-controlled application of the compacting effect and the dual-direction-controlled compacting movement according to the invention, the most effective compaction possible is achieved that reliably produces concrete grades of the highest strength. By directing the compacting effect sufficiently accurately in the flow direction of the concrete mix being cast and thereby into the cast concrete, maximum amount of the applied energy is utilized in compaction, and while simultaneously a component of the compacting movement is applied in a direction perpendicular to the flow direction, good compaction is also assured in the cross-machine direction. Tests performed by the inventor have shown the extremely high importance of the simultaneously longitudinally and perpendicularly shearing compaction movement on the final compaction of the cast product. The compaction result can be further improved by applying the compacting effect on a number of vibrating and mechanically compacting frequencies; however, the effect of multiple frequencies is not as significant as that of the dual-direction compacting movement. The longitudinal vibration combined with the cross-machine compacting movement achieves easy flow of concrete through the casting nozzle, whereby the wear of machine components remains small and no excessive internal pressure is generated inside the casting machine. In comparison with a mechanical compacting movement at a low frequency, the large-amplitude movements working and wearing the concrete mix can be avoided.

By virtue of the multi-directional compaction scheme, shaped objects of a more complicated structure than in the prior art can be moulded, and provided that the auger of the casting machine is equipped with a vibrating means, the flow of the concrete mix along the augers is eased and the wear of the augers reduced. Obviously, the vibrating frequencies of the apparatus are advantageously made adjustable, whereby the vibrations applied at different frequencies can be tuned according to the natural frequencies of the different aggregate particles, whereby the optimal efficiency of energy transfer into the concrete mix is achieved resulting in the most effective compaction.

The invention is next examined with the help of the annexed drawings, in which

Figure 1 is a partially longitudinally sectional view of a casting machine according to the invention;

Figure 2 is a top view of the machine shown in Fig. 1;

Figure 3 is a detail of the diagram of Fig. 1; and

Figure 4 is a cross section of the end product.

The machine according to the invention is an extruder-type casting machine adapted to run along the sides of a casting mould 1 supported by load-bearing wheels 2. The machine is assembled onto a frame 3. The exemplifying casting machine has three conical feed augers 5. The augers 5 are mounted on the frame 3 by means of a drive shaft 7 of the auger. Core-forming mandrels 6 are placed to the trailing end of the feed augers 5 relative to the casting direction. A pull rod 10 adapted to pass through the center of each auger shaft 7 is actuated by a hydraulic cylinder 11 powered by hydraulic machinery 12 via a hydraulic fluid distributing block 12. The end of the drive shaft 7 is provided with a variable-speed reduction gear 8 via which the drive motors 9 of the augers 5 are connected to the auger drive shaft 7. At the input end of the feed augers 5, the top of the machine carries a conical feed hopper 4. Next to the feed hopper 4, at the opposite end of the machine relative to the casting direction, above the machine, are located a mould top plate 16, and at the sides, mould side plates 15, respectively. The side plates 15 are connected to hydraulic cylinders 11. The top plate 16 is connected by means of link mechanism 20 to a drive means of the top plate.

The dual-direction compacting movement according to the invention is accomplished by means of link mechanisms 18 and 19.1, 19.2. As is evident from Fig. 3, the drive shaft 7 is supported by two links 18. When the hydraulic cylinder 11 actuates the pull rod 10, the link mechanism 18 supporting the drive shaft 7, the feed auger 5 and the core-forming mandrel 6 forces these supported components to move forward and downward, or respectively during the opposite-direction movement backward and upward, whereby the concrete mix contained in the extruder section is subjected to a dual-direction-controlled compacting movement. The other limit position of the mechanism 18 is shown by a dashed line in the diagram of Fig. 3. The same compacting movement is also implemented in the mould top plate 16 supported by the link mechanisms 19.1, 19.2 when the crank lever of the link mechanism 20 moves the mould top plate 16 reciprocatingly.

The function of the apparatus is as follows. Concrete mix poured into the feed hopper 4 flows by gravity onto the feed augers 5 rotated by the drive motor 9. The rotating augers 5 propel the concrete mix into a pressurized space continued as the shaping space delineated by the mould 1, the mould side walls 15 and the mould top plate 16. In this space the concrete mix is forced into the space between the core-forming mandrels 6 and the walls 1, 15, 16, where the concrete mix is compacted under the forces of the compacting movements and the internal pressure generated by the core-forming mandrels 6, the moving walls 15, 1, and is thus shaped into the continuous section of the desired end product such as a hollow-core beam, for instance. The reciprocating movement of the core-forming mandrels 6 is provided by the hydraulic cylinder 11 which is connected to the end of the pull rod 10.

The casting machine travels along a platform 1 on wheels 2 propelled by the reaction forces of the extruded concrete mix, or alternatively, the machine can be moved by a separate drive motor. Concrete mix poured in the feed hopper 4 flows by gravity onto the feed augers 5 which propel the concrete mix into the shaping space delineated by the mould walls 1, 15 and 16, thus producing the required internal pressure for moulding. The augers 5 may be arranged to perform a direction-controlled vibrating movement together with the core-forming mandrels 6, whereby the flow of the concrete mix along the flight surface of the auger 5 is eased thus aiding the feed of the concrete mix. The augers 5 are continued as the core-forming mandrels 6 which form the hollow-core cavities 21 required in the end product. Cross sections of different hollow-core shapes are shown in Fig. 4. Compaction of concrete occurs mainly under the effect of these core-forming mandrels 6. The compacting effect is achieved by the direction-controlled vibration of the mandrels 6, advantageously using the reciprocatingly curved swinging movement described above. The mandrel may have a constant cross section if permitted by the cross-sectional shape of the core cavities, since the reciprocating compaction movement also imparts a cross-machine compacting component. In the making of cylindrical core cavities the mandrel may obviously rotate with the auger, while for noncylindrically shaped core cavities a nonrotating mandrel must be used. Obviously, the mandrel cross section may be shaped as tapering or flaring. The direction-controlled compacting vibration permits very large deformations in the flow of the concrete mix. The augers 5 are rotated by the drive shaft 7 and the mandrels 6 are moved with the help of rods 10 adapted to pass through the center of the drive shafts. Besides their rotational movement, the augers 5 can be adapted to perform a compacting movement, whereby their actuation can be combined with the movement of the rods 10.

The rotation of the augers 5 is arranged by means of a drive belt 8 or alternatively a drive chain, and the drive motor is advantageously a hydraulic motor whose speed of rotation is easy to control. Alternatively, an electric motor with a reduction gear can be used. The hydraulic actuator cylinder 11 and pull rod 10 of the mandrels impart the mandrels with the desired direction-controlled vibrating movement, and when the vibrating movement is also desired for the augers 5, they are locked with the help of a lateral-load taking end bearing to the pull rods 10 of the mandrel 6. By virtue of the hydraulic cylinders 11, the mandrels 6 can be actuated with a constant force and constant acceleration, which is advantageous with regard to minimizing the stresses imposed on the machine structures. Obviously, the hydraulic cylinders can be replaced by other types of actuators such as eccentric cam mechanisms and other devices capable of generating an essentially sinusoidally varying acceleration. In a hydraulically driven machine using a conventional hydraulic machinery as the vibrating power source, the machinery output power is controlled in hydraulic pulses to the different vibrating actuators. To minimize the vibrations induced in the machine structures, the hydraulic drive pulses should be properly phased. The vibrating frequency can be varied by suitable control of the hydraulic fluid distributing block, while the vibrating force is adjusted by varying the operating pressure of the hydraulic actuators.

The compaction movement according to the present invention occurs in the form of an accurate direction-controlled vibrating movement in lieu of low-frequency shearing compaction. In fact, the borderline between shearing compaction and vibrating compaction is difficult to define, and therefore, the appropriate vibrating frequency for each case is essentially dependent on the properties of the concrete mix to be cast. Typically, the vibrating frequency for concrete is in the order of 12.5 - 200 Hz. In this machine the vibrating frequency of the mandrel section has been found to advantageously lie in the range 12.5 - 50 Hz, and of the mould top and side plates, in the range 5 - 10 Hz. This combination of two different frequencies is particularly advantageous as the vibrating effect is then imposed on aggregate particles of widely varying size.

In addition to those described above, the invention can be implemented in alternative embodiments.

The drive elements can be any power actuators capable of delivering the required output power. In the above applications, however, electric or hydraulic motors are superior. The conversion of a rotational movement into a linear cyclically reciprocating motion can be implemented in different ways using, e.g., a crank lever or eccentric cam and follower mechanism. All drive elements are advantageously controllable.

The direction of the compaction movement can be controlled by varying the lengths and directions of the links in the supporting link mechanism. If the links are directed slightly backward with respect to the casting flow direction, the swing movement occurs downward, whereby the compaction effect imparted by the mandrels, for instance, becomes more pronounce in the concrete mix located below the mandrels. Correspondingly, by aligning the links slightly forward tilted along the casting flow direction, the compaction movement can be forced to occur upward directed. Furthermore, the trajectory of the compaction movement of the link mechanism can be varied by modifying the lengths of the links, and in fact, the links of any link mechanism can have different lengths. Also if the compaction movement is implemented with the help of an eccentric cam mechanism, the trajectory of the compacting elements can be varied in a similar manner. Besides link and eccentric mechanisms, other equivalent types of movement controlling means such as guide rails can be used permitting the implementation of almost any conceivable shape of compaction trajectory.

While in the above-described embodiment the mould side plates are moved only longitudinally with respect to the casting flow direction, it is conceivable that at least some of the mould side plates are connected to an eccentric mechanism capable of imparting a vertical or lateral movement. Also the other compaction movements can be implemented so that transverse compaction movement relative to the casting flow direction occurs in the horizontal plane. Moreover, an eccentric mass vibrator 17 can be placed inside the core-forming mandrels, whereby the compaction effect is further improved and the flow of the concrete mix eased. The compaction movement or compaction efficiency can be controlled by varying the speed, stroke length or input power of the compaction movement.

Claims

1. A method of producing a compacted concrete product, in which method
   - concrete mix is forced by means of at least one feed means (5) through a delineated cross section (1, 6, 15, 16) for the purpose of manufacturing a concrete product with a desired cross section, and
   - the concrete mix to be cast is compacted by means of at least one mechanical reciprocating compaction movement,

   characterized in that

   - at least one of said compaction movements is a direction-controlled reciprocating movement incorporating at least one first translational component in the direction of the casting flow of concrete and at least one translational component perpendicular to the at least one first translational component.

2. A method as defined in claim 1, **characterized** in that at least one of the compaction movements is comprised by the movement of a core-forming mandrel (6) adapted to the space of delineated cross section, said movement being carried out both longitudinally along the casting flow direction and at least essentially transversely to said casting flow direction.

3. A method as defined in claim 1, **characterized** in that the feed means (5) performs a movement connected to the movement of the core-forming mandrel (6).

4. A method as defined in claim 1 or 2, **characterized** in that at least one of the compaction movements is comprised by the movement of a mould top plate (16) adapted to border the space of delineated cross section, said movement being carried out both longitudinally along the casting flow direction and at least essentially vertically transversely to said casting flow direction.

5. A method as defined in claim 2 or 4, **characterized** in that the compaction movements of the core-forming mandrel (6) and the mould top plate (16) are carried out at different frequencies.

6. A method as defined in any foregoing claim, **characterized** in that the concrete mix is additionally compacted by subjecting the mix to high-frequency compacting vibration.

7. An apparatus for producing a compacted concrete product, said apparatus comprising
   - at least one feed means (5) for feeding concrete mix through a delineated cross section (1, 6, 15, 16),
   - at least one such surface delineating said cross section (1, 6, 15, 16) that can be brought to a direction-controlled reciprocating movement for the purpose of compacting the concrete mix, and
   - elements (11, 20) capable of actuating the movement of said surface

   characterized by

   - elements for controlling the movement direction of said surface (6, 16) so that said compaction movement has at least one first translational component in the direction of the casting flow of concrete and at least one translational component perpendicular to said at least one first translational component.

8. An apparatus as defined in claim 7, said apparatus comprising at least one core-forming mandrel (6) extending into said space of delineated cross section and further comprising elements (8, 9, 11) for implementing the reciprocating movement of the mandrel (6), **characterized** by elements (18) for controlling the movement direction of the mandrel so that the mandrel (6) can be moved simultaneously both along the casting flow direction and perpendicularly to this direction.

9. An apparatus as defined in claim 8, said apparatus comprising a mould (1) forming a space of delineated cross section, two mould side planes (15) with a movement actuated by an actuator (11) and a mould top plate (16) actuated by an actuator (20) and at least one core-forming mandrel (6), **characterized** by elements (19.1, 19.2) for controlling the movement direction of the mould top plate (16) so that the mould top plate (16) can be moved simultaneously both along the casting flow direction and perpendicularly to this direction.

10. An apparatus as defined in claim 9, **characterized** by the adaptation of a conventional high-frequency vibrator to the interior of the core-forming mandrel (6).

11. An apparatus as defined in claim 8, **characterized** in that the direction-controlling elements (18) are formed by parallel links.

12. An apparatus as defined in claim 8, **characterized** in that the direction-controlling elements (18) are formed by nonparallel links.

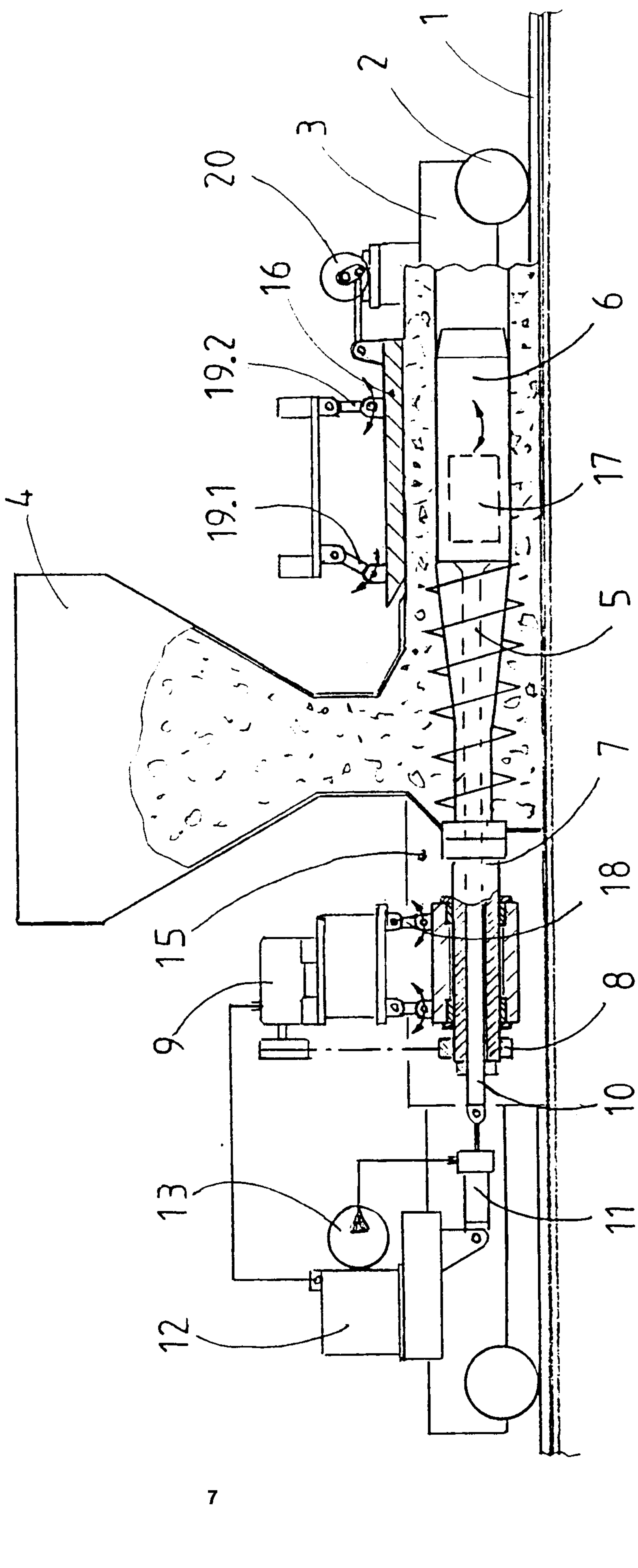


FIG 1

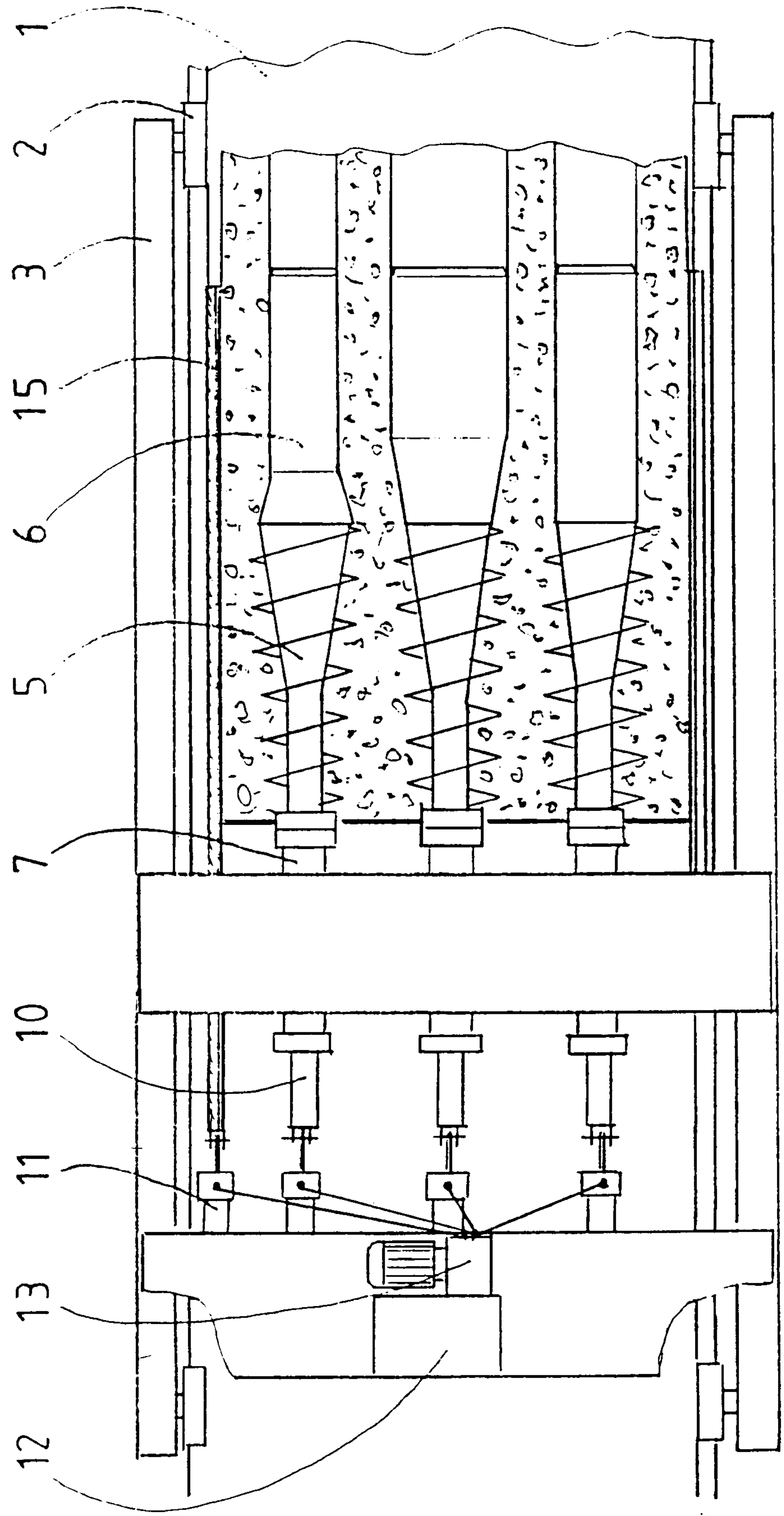


FIG 2

FIG 3

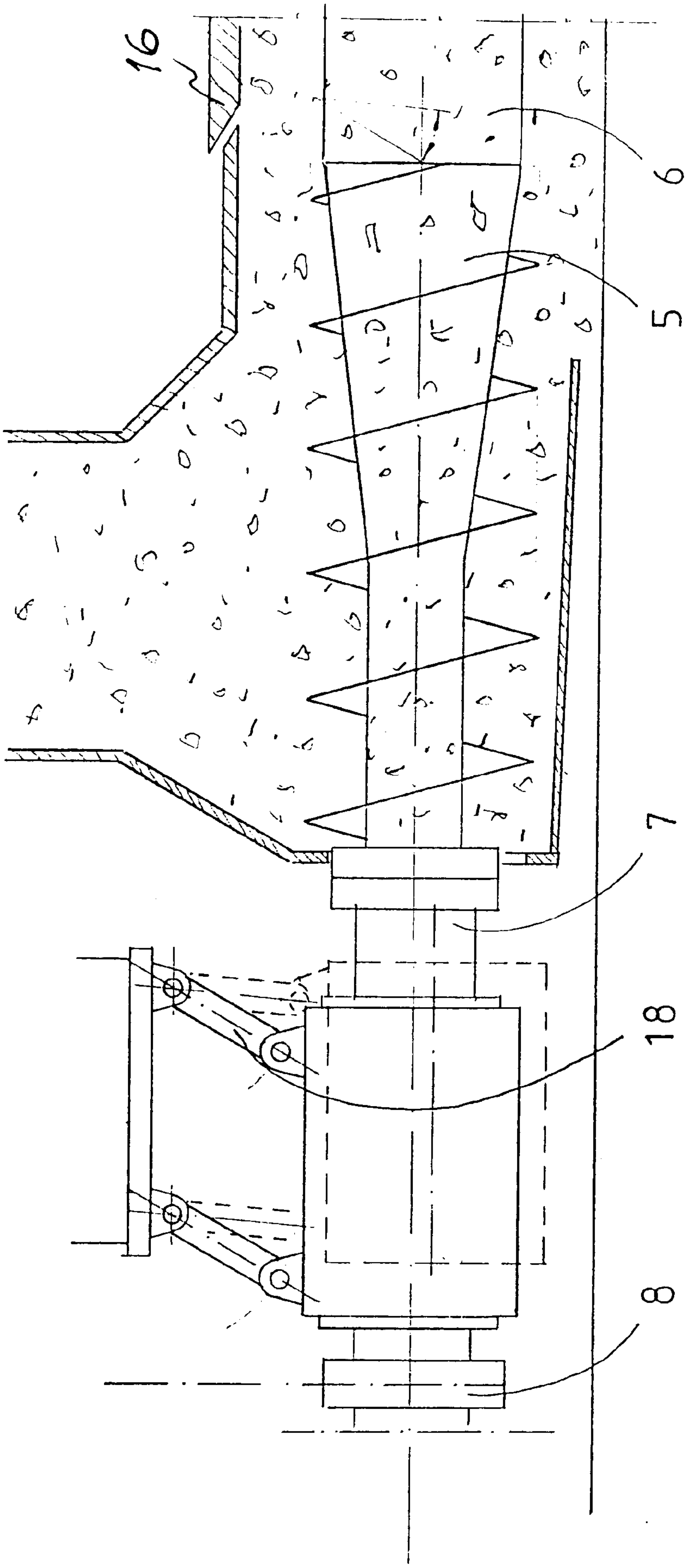
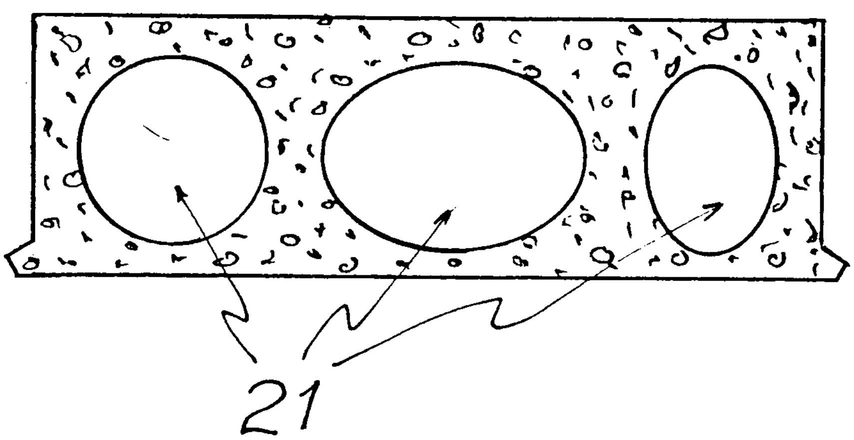


FIG 4



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EUROPEAN SEARCH REPORT

Application Number
EP 95 85 0070

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	CH-A-477 964 (BEAM BRITISH ENGINEERING APPLICATION OF METAL ESTABLISHMENT) * the whole document * ---	1,7,9	B28B1/08
X	SOVIET INVENTIONS ILLUSTRATED Week 8425, 1 August 1984 Derwent Publications Ltd., London, GB; AN 84-157227/25 & SU-A-1 046 102 (YAROSL POLY) 7 October 1983 * abstract * ---	1,4,7,9,11	
X	SOVIET PATENTS ABSTRACTS Week 8901, 15 February 1989 Derwent Publications Ltd., London, GB; AN 89-006824/01 & SU-A-1 405 993 (YAROSL POLY) 30 June 1988 * abstract * ---	1,4,7,9,12	
A	EP-A-0 175 930 (INDUCO OY) * the whole document * ---	1-12	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B28B
A	EP-A-0 192 884 (OY PARTEK AB) * the whole document * ---	1,4,7,9,11,12	
A	EP-A-0 229 751 (KT-SUUNNITTELU OY) * the whole document * ---	1-3,7,8,10	
A	EP-A-0 241 172 (KT-SUUNNITTELU OY) * the whole document * -----	1,4,7,9,11,12	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 July 1995	Gourier, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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