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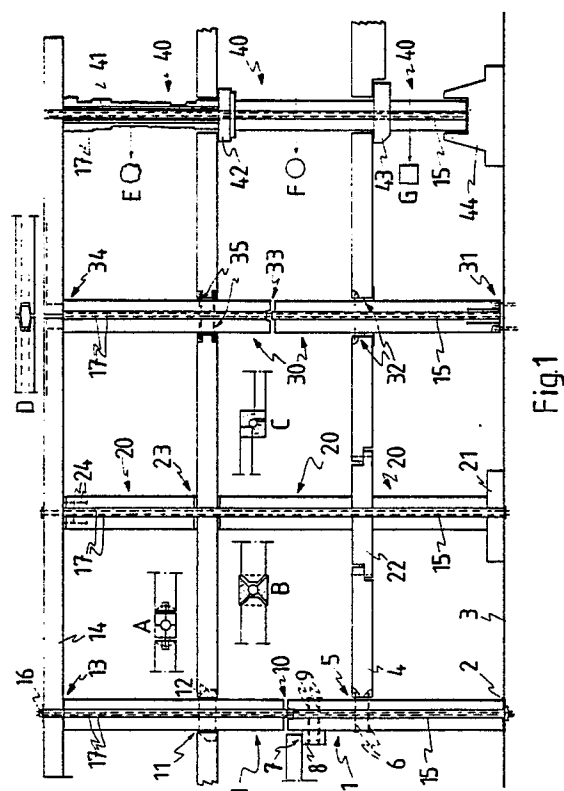
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Concrete framework system and method and apparatus for fabrication of system-compatible columns.

A concrete framework system for a building comprises columns (1,20,30,40)* each formed by at least two vertically aligned column sections, and supporting structures (6,12,22,35) arranged in or between column sections providing supporting means to join horizontal structural elements (4,14) to the columns (1,20,30,40). Each column section has a cavity (15) extending longitudinally from end to end, and at least one prestressing tendon (17) is arranged to pass through the cavity. A method of fabricating the columns comprises feeding stiff concrete mix (56) into a vertically aligned mold (50,51) the mix (56) being compacted under pressure in the mold (50,51) by means of a shaft-like compaction member (54) which is aligned coaxially with the axis of the mold and is provided with profiling protrusions (60).



The present invention relates to a concrete framework system for a building and also concerns a method and apparatus for the fabrication of system-compatible columns.

Known in the prior art are several alternative fabrication methods and jointing systems. The most frequently employed arrangement today is a contiguous vertical framework supporting beams of short span. In this arrangement, the vertical frame elements, or columns, are constructed as single elements extending three or four storeys in height, or alternatively, by jointing individual elements of maximum practical length. In the latter case, the horizontal primary beams are spanned between columns and supported by various types of column brackets.

Disadvantages of the above arrangement are increased production costs due to the numerous column brackets, and the need for individual design and dedicated mold setups. In addition, if the column section is to be altered from one storey to another according to the load, standard mold sets cannot be used for fabricating the column. Furthermore, the horizontal beam system of the above-described arrangement does not provide a contiguous beam framework but rather acts as a so-called single-bay supporting beam, requiring a beam section approximately 20% greater than conventional designs.

A system of contiguous horizontal beam frameworks together with single-storey-high columns can also be used. This system has mainly been applied in on-site building, being used less frequently in element construction technology.

Naturally, supporting dual-bay beams have been utilized, but a hindrance to the use of these longer supporting beams has been the lack of a suitable jointing method.

The jointing of stiff beams and columns has been employed in element construction by fabricating the columns and beams as hollow-core elements. In this method, the columns have been a single-storey height, with the beams extending from column to column. A satisfactory joint has been achieved by inserting reinforcement steel members into the ends of the hollow-core elements with the members extending through the joint to be formed, and filling the element ends with grouting concrete.

The above-described method disposes of the need for column brackets, and forms the column/beam framework into a contiguous structure. However, one disadvantage of the method is the considerable worktime spent in the preparation of reinforcement steel members at the construction site.

A less common solution is one in which the main reinforcement steel members are made to

extend beyond the element end by a length equivalent to the bond anchorage length of the members. However, this solution can only be used in exceptional cases.

Thus far, methods of manufacturing framework elements have been such as to require a high proportion of manual labour and individual design. So-called mass-produced standard catalog products, such as piles, have been absent from the marketplace.

The most conventional production method for the fabrication of a column or beam is the mold-casting method, in which the columns and beams are produced in individually prepared wooden or steel molds. The molds are almost invariably placed horizontally, and casting is performed, using a relatively fluid mix of concrete, by metering the fluid mix under manual control from the concrete feed hopper into the mold, whereupon the cast mix is vibrated using high-frequency vibrators or mold-mounted vibrating equipment.

Prior to casting, frogs and bracket shapes may be preworked into the molds, along with individual reinforcement steel members.

Alternatively, the columns and beam have been fabricated in long pretensioning yards so that molds are placed in a line on an elongated casting bed.

The placement of steel reinforcing members within the elements as well as their pretensioning takes place prior to casting. Afterwards, detensioning takes place as soon as the concrete reaches its release strength.

The disadvantages of these techniques include the need for a fluid concrete mix, a factor related to the low-level of compacting technology employed, resulting in increased hardening time, and moreover, a significantly higher consumption of cement in order to achieve a high final strength. The reinforcement operation involves a high proportion of manual work as well as the making of molds. Bracket structures required to form element frogs also demand a high degree of manual work on the molds in addition to the extra reinforcement necessary.

The aim of the present invention is to overcome the disadvantages associated with the afore-described prior art techniques and achieve an entirely new kind of concrete column framework system together with a method and apparatus for fabricating system-compatible columns.

The invention is based on fabricating a concrete column in a mold of desired shape in a continuous slip-form casting process by means of a vertical casting machine using extremely stiff concrete mix, whilst forming a hollow core in the centre of the column. After the column is cured, steel reinforcement members are inserted into the

hollow core and are post-tensioned against the column ends. A hardening compound is injected around the stressed reinforcement. In addition, columns in accordance with the invention may be shaped in such a way as to locate the hollow core as close as possible to the centre of the column with the inner wall of the column profiled to the shape of, for example, a helical thread in order to achieve an improved anchorage.

More specifically, according to a first aspect of the invention there is provided a concrete element framework system comprising vertical concrete columns including at least two vertically jointed column sections, and support structures arranged in or between the column sections to provide supporting means for the jointing of horizontal framework elements to the columns, characterized in that each column section is provided with a cavity extending longitudinally through the section such as to facilitate the formation of vertically jointed column sections into a combined column structure having a contiguous, preferably coaxial, cavity extending through the entire height of the structure, and at least one prestressing tendon extends through said cavity and is tensioned by means of anchoring couplers arranged at the ends of the column structure, whereby a hardening compound may be injected about the prestressing tendon in order to provide final anchorage of the tendon.

According to a second aspect of the invention there is provided a method of fabricating concrete columns, in which a concrete mix is fed into a mold, and the mix is compacted by compacting means, characterized in that the concrete mix is a stiff concrete mix and is fed into a vertically aligned mold, and the mix is compacted under pressure in the mold by means of a shaft-like compacting member which is aligned substantially coaxially with the longitudinal axis of the mold and is provided with profile-generating protrusions.

Finally, according to a third aspect of the invention, there is provided apparatus for fabricating concrete columns, comprising a mold, feeding means for feeding a concrete mixture into the mold, and compacting means for compacting the mix in the mold, characterized in that the mold is aligned essentially vertically, the feeding means and the compacting means are movable in relation to the mold, and the compacting means comprises a compacting member which is aligned in its operational position substantially coaxially with the axis of the mold and extends longitudinally through the entire height of the mold.

The framework in accordance with the invention, together with its advanced production technology and method of fabrication, can cope with a non-standard product and jointing method whilst using the machinery of mass-production technol-

ogy. In this framework, each column is typically comprised of several elements, each of which exactly meets the local design values by its load characteristics as well as the architectural aspects of the application. In addition, the system features stiff joints, capable of transmitting, for example a bending moment for the columns to the beams, thus making the structure act as a contiguous frame structure and providing constructional advantages both during the erection phase of the building and in the overall stability of the final construction. Furthermore, the system gives freedom of choice in the use of post-mountable brackets, frogs, supports, spacers, or structural jointing fixtures.

Since the products are of exceptionally high quality by virtue of the developed production method, it is possible, when required, to design the columns for relatively high tensile stresses as well as for a larger number of prestressing tendons. Thus, the column is provided with a bending stress capability of constant magnitude in all directions such as to allow stiff jointing of beam structures and the transmission of supporting moments to the columns without necessitating the addition of auxiliary reinforcement members locally to the joint. Consequently, calculations of the joint's load capacity are reduced to the selection of a standard product from a catalog on the basis of the appropriate column dimension and the determination of a required pretensioning stress. By virtue of this, structural elements may be fabricated in advance without prior information as to their final application. Later, when the application is defined, the elements of the column are jointed and trimmed to the exact length required by, for example, sawing, and thereafter the post-tensioning stress is applied and the core cavity filled with a hardening compound.

As the prestressing tendons are located in the centre of the columns, the fire- and corrosion-protective concrete layer covering the steel reinforcement is thicker in comparison with a construction having the reinforcement placed close to the column's surface. Since the steel members are prestressed, an additional benefit is gained by the avoidance of compressive stresses on the members in a loaded column. Also avoided is the danger of generating tensile stresses within the concrete section of the column structure when the column is contracted under axial stress. Consequently, elements manufactured in accordance with the method of the invention do not contain stirrup steels or longitudinal prestressed steel members placed close to the outer surface of the column. Thus, elements manufactured in accordance with the method of the present invention are reinforced only by the prestressing tendons absolutely essential to the column's structure.

Columns compatible with the system can be cast by using different molds, each individually designed as to its shape, size, surface structure, and reinforcement. The casting of columns with the help of the developed casting apparatus uses extremely stiff concrete mix compacted by a shear-compacting method which totally avoids the use of conventional high-frequency vibrators. By virtue of the efficiency of the shear-compacting method and the use of an extremely stiff concrete mix, the cast columns achieve a strength appreciably higher than by using conventional methods (strength values of 50 ... 150 MN/m² are possible as compared with the strength of conventional grades of 20 ... 40 MN/m²). Thus, columns manufactured by the method in accordance with the invention may have smaller sections than conventional structures, allowing cost savings in material. In addition, due to the pretensioning method, stress peaks in prestressing tendons remain insignificant. Furthermore, the production method enables the uncomplicated alteration of column sections during the manufacturing process.

Various embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a cross-sectional side view of one example of the concrete column framework system in accordance with the invention, illustrating different forms of column and joint systems which may be used; and

Figure 2 shows a cross-sectional side view of one example of slip-form casting apparatus in accordance with the invention.

Figure 1 illustrates the use of practical embodiments of products fabricated in accordance with the invention. A column structure 1 with a longitudinal hollow core 15 may be mounted at the construction site and post-tensioned in a ready-mounted structure. Here, the column 1 is anchored via a first tensioning anchor 2 to the base structures 3. Anticipating a joint 5 of the column 1 and a beam 4, holes are drilled at the construction site into the hardened concrete for mounting bolts 6 required for jointing the beam 4, after which the actual jointing of the beam 4 is implemented using mechanical fixtures. A separate console 8 of a joint 7 is correspondingly fixed by drilling holes in the column 1 at the construction site and fixing the console 8 to the column 1 with help of bolts 9 pushed through the holes. A column extension joint 10 is implemented by forming the column elements into, e.g., mating male and female elements so that the column elements during erection are guided to an accurate alignment without the danger of displacement on account of lateral tolerance. In a joint 11, between the column structures, there is mounted a separate steel structure 12 which simulta-

neously operates as an extension of the column and a support for the beam, so that the beams need not be separately fixed but instead, due to the guiding effect of the groove, are directed to the correct position. Marked with A in the diagram is illustrated the cross-section of the column 1 at the joint 11. Correspondingly, a beam structure 14 at a joint 13 is attached to form an extension of the column 1 so as to achieve stiffening of the joint 13 by the pretensioning stress of tendons 17 stretched through the cavity 15 between a first 2 and a second 16 tensioning anchor. In the post-tensioning operation, the anchorage of the stranded tendons 17 may be implemented using separate mechanical anchors 2 and 16, or, alternatively, by the bond anchorage. After post-tensioning, the cavity 15 is pumped full of a hardening compound.

A column structure 20 is similarly factory-assembled and tensioned. In the same manner, to the column 20 is attached a base element 21, thus disposing of a separate column jointing to the building's base. Furthermore, a beam element 22 is mounted between the column, thus making it unnecessary to perform actual jointing of columns and beams at the construction site. A joint 23 is correspondingly provided with a column extension/supporting frog of steel or special high-strength concrete as a part of the column structure. This kind of a system-compatible concealed column extension/supporting frog section need not be separately protected by grouting at the construction site, because the combined steel/concrete or the special high-strength concrete structure, jointed at its visible sections, provides a sufficient fire resistance and compression strength capability comparable with that of the column structure itself. The diagram section marked as B illustrates the cross-section of the column 20 at the joint 23. Correspondingly, the diagram section marked as C, illustrates an alternative embodiment of a cross-section of the column 20 at the joint 23. The joint/supporting bracket section may be selected to have a desired shape as required by the beam structure to be jointed and construction technology to be applied.

The beam 14 may also be attached to the end of the column 20 by means of mechanical fixtures 24, which also provide for stiffness of the joint. A column structure 30 may also already be equipped in conjunction with the casting operation with various fixtures such as, e.g., column fixing stirrups 31. Furthermore, anchoring plates 35 or frogs 32 necessary for jointing may be preplaced during the casting operation of the column in conjunction with the fabrication of the spiraling parts of the longitudinal cavities 15. Joints 33 of column extensions need not be limited to the joints of the columns or beams or joints at the supporting brackets but

instead, may be freely located in relation to the joint 33 inbetween the floors or at a desired point of the framework. An upper joint 34 may also be implemented so as to have a tapered end of the column 30. The diagram section marked as D illustrates a top view of this embodiment. Column elements fabricated according to the system may have a desired shape, size, and surface structure as illustrated in a column structure 40. Diagram sections marked as E, F, and G illustrate respective cross-sections of each column section of the column structure 40. This embodiment achieves freedom of design without compromising the production method of the structure. Thus, it may be complemented by attaching, e.g., architecturally designed structural elements 41 or consoles 42 and 43. The column structure 40 may also be provided with a base 44. Moreover, the size and shape of the structure may be varied as required by the specifications of designed space and loading capacity rating.

A typical column in the system is assembled from, e.g., individually designed column sections for each storey, as well as from fixtures required for jointing the beams or other operations of erection.

Figure 2 illustrates a typical column-casting machine for fabricating column elements in accordance with the system. The mold of the casting machine comprises vertically mounted mold sides 50, which may be individually designed as to their horizontal and vertical dimensions and surface structure. The mold also incorporates a bottom 51 with adjustable height. The production method is typically applied to the fabrication of a column section 61 of relatively short length, limited to a height from one to two storeys. Prior to commencing operations, an actual casting machine 52 is mounted above the mold sides 50. The casting machine 52 is transferred with help of an auxiliary lift (not shown) by a lifting eyelet 53 above the mold. In this posture, a spiraling tube 54 protruding from the casting machine 52 body reaches through the length of the casting mold down to the bottom 51 and is resting on the bottom. The spiraling tube 54 forms in the center of the column section 61 a longitudinal cavity, which is utilized in the post-tensioning operations of columns.

The actual casting operation is started by filling a concrete hopper 55 with an extremely stiff concrete mix 56. Casting is started by switching power to a motor 57 of the casting machine 52, allowing the motor to rotate via a coupling means, e.g., a first belt 58, an auger 59, and, via a second belt 62, the spiraling tube 54. When the mold 50, 51 starts to fill, the spiraling tube 54 and especially its flight 60 creates a working effect, which causes internal shear in the concrete mix, resulting in a gradual

compaction of the mix. Concrete compaction becomes effective only at the stage where the mold 50, 51 is entirely filled with concrete and the auger 59 forms a pressurized space in the mold 50, 51. Consequently, the actual compaction is achieved under pressure by virtue of the spiraling tube 54, and especially, the working effect produced by its flight 60, which generate internal shear in the mix and compact it. When the concrete mix has achieved a sufficient degree of compaction, the casting operation may be stopped. Due to the extreme stiffness of the mix, it retains the shape into which it was compacted at the end of the casting operation. The casting machine 52 is disconnected from the casting mold by lifting at the eyelet 53 of the casting machine and simultaneously rotating the spiraling tube 54 so as to make the spiraling tube rotate counterclockwise along the spiral worked into the stiff concrete mix without breaking the internal structure of the cast concrete. Consequently, the stiff concrete retains the internal spiral profile formed by the spiraling tube 54, thus providing a good anchorage capability for prestressing tendons 17 to be inserted in the final structure as well as for the hardening compound embedding the tendons.

Accordingly, the column section 61 retains its shape directly after casting and, when required, may be lifted upwardly from the mold and transferred to the final heat-curing oven. For this purpose, a rod (not shown) is inserted through the cavity formed in the center of the column section 61 and fixed to the bottom 51. With help of the lifting rod and the bottom 51, the yet uncured column section 61 may be lifted up from the mold with the precondition that the mold is provided with sufficient release draft or is capable of being opened.

The size and shape of the mold may be designed as desired, making it possible to use column sections of square, circular, oval or varied shapes. In addition, the column mold may be provided prior to the actual casting operation with anchoring steels, such as a complete set of column anchoring stirrups over the bottom 51, or with column brackets or anchoring plates placed to the intermediate sections of the mold. All side surfaces of the column 61 achieve an extremely high quality by virtue of the steel-plate mold surface used on all sides while the production method assures a high grade of compaction in the concrete.

Separate supporting brackets or architectural elements compatible with the system are manufactured at an alternative site to deliver them ready-made to be inserted into the final column element as part of the structure, thus avoiding interruptions in the fabrication of the actual modular elements in the rationalized manufacturing process.

The quality of concrete mix used for fabricating structural elements in accordance with the system is selected to be of such grade that does not crack when subjected to stresses by fire and load. However, the system does not set any special prerequisites for the concrete quality, since the extremely stiff concrete mix used in the method inherently guarantees satisfaction of requirements set above. In respect to a fire situation, an important design factor is to provide the concrete with a sufficient quantity of protective pores which allow the moisture stored in the concrete to be released without causing cracks in the concrete structure. Additionally, cracking may be eliminated by mixing into the concrete auxiliary material, e.g., fibers (steel, glass, polypropylene, mineral or carbon fibers) and pore-generating admixtures.

Fill-casting of the column cavity may also utilize fibers of the aforementioned kind to eliminate tensile stresses generated by the prestressing forces. Columns compatible with the system may also be jointed to form a part of a concrete beam framework or steel beam framework.

Claims

1. A concrete element framework system comprising vertical concrete columns (1,20,30,40) including at least two vertically jointed column sections, and support structures (6,12,22,35) arranged in or between the column sections to provide supporting means for the jointing of horizontal framework elements (4,14) to the columns (1,20,30,40), characterized in that each column section is provided with a cavity extending longitudinally through the section such as to facilitate the formation of vertically jointed column sections into a combined column structure (1,20,30,40) having a contiguous, preferably coaxial, cavity (15) extending through the entire height of the structure, and at least one prestressing tendon (17) extends through said cavity (15) and is tensioned by means of anchoring couplers (2,16) arranged at the ends of the column structure (1,20,30,40), whereby a hardening compound may be injected about the prestressing tendon (17) in order to provide final anchorage of the tendon.

2. A concrete framework system according to claim 1, wherein the cavity (15) extending longitudinally through each of the column sections, is provided with a profiled grooving, for example winding helically, to improve the adherence of the injected compound that provides anchorage for the prestressing tendon (17).

3. A method of fabricating concrete columns, in which a concrete mix (56) is fed into a mold (50,51), and the mix (56) is compacted by com-

pacting means (54), characterized in that the concrete mix (56) is a stiff concrete mix and is fed into a vertically aligned mold (50,51), and the mix is compacted under pressure in the mold by means of a shaft-like compacting member (54) which is aligned substantially coaxially with the longitudinal axis of the mold and is provided with profile-generating protrusions (60).

4. A method according to claim 3, wherein the mix (56) is compacted by rotating the shaft-like compacting member (54) about its axis by means of a rotating apparatus (57,58).

5. A method according to claim 3, wherein the mix (56) is compacted by moving the shaft-like compacting member (54) in a reciprocating manner in the axial direction.

6. Apparatus for fabricating concrete columns, comprising a mold (50,51), feeding means (55,59,57,58) for feeding a concrete mixture into the mold (50,51), and compacting means (54,60,57,62) for compacting the mix in the mold (50,51), characterized in that the mold (50,51) is aligned essentially vertically, the feeding means (55,59,57,58) and the compacting means (54,60,57,62) are movable in relation to the mold, and the compacting means comprises a compacting member (54) which is aligned in its operational position substantially coaxially with the axis of the mold (50,51) and extends longitudinally through the entire height of the mold (50,51).

7. Apparatus according to claim 6, wherein the compacting member (54) is provided with profiling protrusions (60).

8. Apparatus according to claim 6 or claim 7, wherein the compacting means incorporates a rotary drive (57,63) by means of which the compacting member (54) can be rotated about its axis.

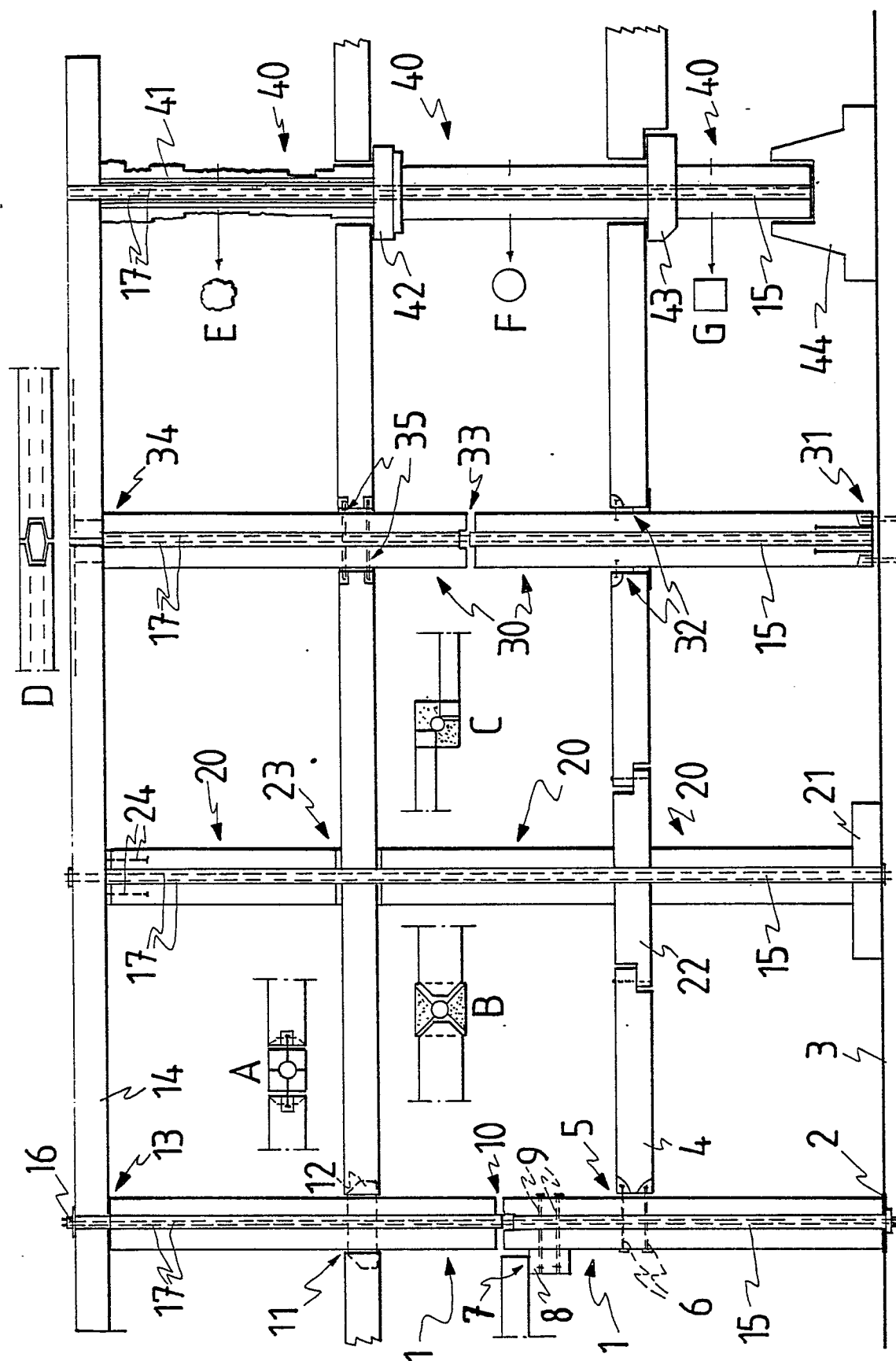


Fig 1

