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(71) Applicant : **NORWEGIAN CONTRACTORS a.s.**
Holtet 45
N-1320 Stabekk (NO)

(72) Inventor : **Nyhus, Kjell Arne**
Granveien 2
N-3440 Royken (NO)

(74) Representative : **Jackson, Peter Arthur**
Gill Jennings & Every, 53-64 Chancery Lane
London WC2A 1HN (GB)

(54) Method and apparatus for constructing long span, shell-shaped, substantially horizontal concrete structures.

(57) Method and apparatus for constructing long span reinforced shell-shaped, substantially horizontal concrete structures. The concrete structures art constructed in a continuous casting process by utilizing a inclined casting surface (26) and by applying a completely or partly displaceable or movable formwork (27). The formwork (27) comprises a number of joining formwork modules (18) which repeatedly are moved from the front end (31) of the formwork to the rear end (33) of the formwork. Reinforcement are mounted and prestressing cables are tightened, and these operations are carried out independently of the casting process. During the continuous casting process, the complete structure is sequentially moved in a forward direction with and without the formwork until the concrete structure has achieved a desired length.

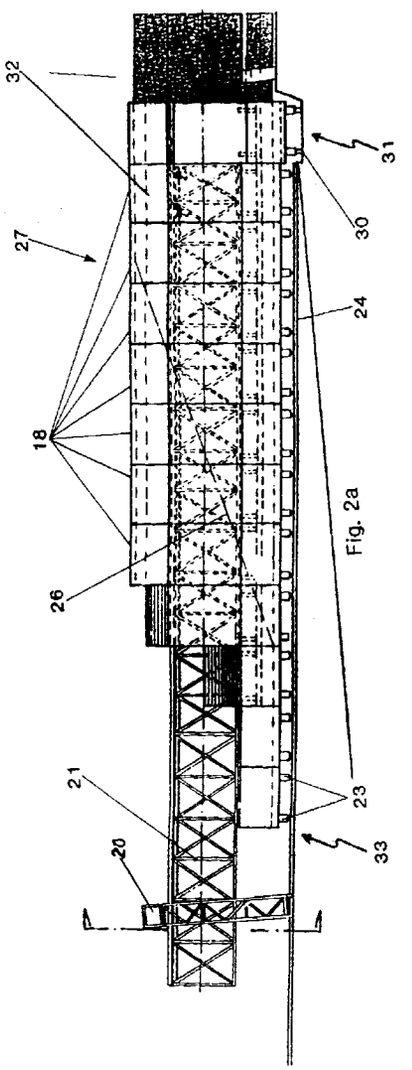

Fig. 2a

EP 0 500 221 A1

The present invention relates to a method and an apparatus for constructing long span, shell-shaped, substantially horizontal concrete structures.

More particulary the invention relates to shell-shaped concrete structures which are utilized in constructing submerged tubes (bridges, tunnels), pipe bridges and floating bridges, but also in general where such long span, shell-shaped, substantially horizontal concrete structures are utilized, and where the requirements to homogenity, water-tightness and strength are important.

Traditionally, such long span, shell-shaped concrete structures are assembled by prefabricated elements which are constructed by known methods, for example constructed in a floating vertical position by conventional slip-forming methods, eventually constructed in a dry dock or at a construction site (yard), whereafter the elements are transported to the final construction site and assembled. The assembly of the elements is carried out, for example by means of bolts for pulling the elements together, and thereafter by using prestressing cables for tightening the elements together.

The known methods can be applied on the assumption that sufficient water-tightness and strength are achieved in the joints. The joint between the elements is a weak part in relation to both strength and water-tightness. Experience has shown that such joints have a tendency to leak, and thereby increase the maintainance costs. Therefore, these joints must be considered as undesirable elements regarding the overall strength of the structure.

In the present invention such long span, shell-shaped, substantially horizontal concrete structures are constructed as a continuous (homogeneous) concrete structure without joints. The problem related to the water tightness of the joints is avoided and a substantial increase in strength of the structure is achieved because the joints between the reinforcement bars of the structure are not located at certain locations, which is the case for conventional methods utilizing prefabricated elements, and in addition the joints for joining the prestressing cables together can be distributed over the complete length of the structure. Another substantial advantage of the solution is that no elements or the like transversally perforate the concrete wall, hence the risk for leakage is avoided.

When constructing long span, shell-shaped, substantially horizontal concrete structures for various purposes, i.e. submerged tubes, floating bridges, water pipes, sewers, hydrocarbons or pipes/channels for irrigation purposes, a technical and economical advantageous solution is achieved compared to previously known techniques. According to the present invention, the shell-shaped, substantially horizontal concrete structures are continuously constructed in an approximately horizontal position and by means of a number of longitudinal movable formwork modules, each comprising at least two outer and two inner formwork elements.

The present method is characterized in that the concrete structure is constructed in a continuous casting process by applying a substantially horizontal formwork apparatus with continuous supplying of fresh concrete with suitable consistency and by establishing, in relation to the horizontal plane, a free rearwardly inclining freely exposed casting surface. The method comprising the steps of applying a completely or partly displacable and removable formwork unit comprising a plurality of - in the operation mode - mutually joined formwork modules which sequentially and repeatedly are moved from the front end of the formwork to the rear end of the formwork, the concrete structure together with the formwork unit being moved forward in conformity with the curing speed of the concrete at the front end of the formwork, until the complete concrete structure has achieved a desired length.

The operation is carried out in a continuous process with inclined casting surface, in which fresh concrete is supplied all the time. Reinforcing bars and ducts for prestressing cables are installed in front of the casting surface.

The installation and tightening of the prestressing cables are carried out in a known manner from recesses in the wall after the formwork elements are removed. New cable lengths are connected to already prestressed cables and thereafter prestressed. After prestressing, the cables are grouted and the recesses are closed by concreting.

The present invention will be described in more detail below by means of a preferred embodiment, in which the present method is utilized in constructing a submerged tube. The construction of the tube is carried out by means of modules, each module comprising six outer and six inner formwork elements. The method will further by made clear by reference to the accompanying drawings, wherein:

Fig. 1 is an elevation view showing a known method for joining two prefabricated elements together according to the prior art;

Fig. 2a is an elevation view showing the casting of a tunnel according to the present invention;

Fig. 2b is a sectional view of the tunnel;

Fig. 2c corresponds to the front end of Fig. 2a prior to casting;

Figs. 3a-e are phase drawings showing a method for the assembly of the outer and inner formwork including working platforms, reinforcements, etc; and,

Fig. 3f is a detail showing prestressing cables.

Traditionally, such tunnels are built up by prefabricated elements 1, 2, see Fig. 1. The elements are towed to the installation site, and joined together by bolts and sealed with a rubber sealing 3 as a first sealing and joint, whereafter the recess 4 is filled with con-

crete.

The production apparatus according to the present invention mainly consists of, as shown in Figs. 2a-c and 3a-f, a base 23, a skid 24, a number of formwork modules 18 comprising outer formwork elements 6-11 and inner formwork elements 12-17, a support beam 2 with the first end supported on a support frame 20 and the second end on a temporary support 28 prior to casting of the first module, thereafter inside the cured part of the concrete structure 32. The formwork elements 6-17 are mounted together behind the curing surface (in front of support frame 20) and they are demounted in a demounting pit 30 located in the front end of the structure. A detailed description of the apparatus will be further debcribed by a preferred embodiment of the invention with reference to the drawings in which the same reference number refers to the same part in all the drawings.

According to the preferred embodiment of the invention, the tube is constructed in accordance with the following method:

– The bottom elements 6, 7 of the outer formwork, see Fig. 3a-f, are mounted on the base 23 which can be moved on a skid 24, and reinforcements (reinforcing bars and ducts for prestressing cables) are installed in the lower part of the structure.

– The inner formwork comprising elements 12, 13, 14, 15, 16, 17 including working platforms 25, is mounted to support beam 21, and the installation of the reinforcement is completed. The support beam 21 is in the first end supported on support frame 20 and in the other end at "seaside" supported inside the cured tube 32. Initially, and prior to completion of the first module 18, a temporary support 28 for supporting the support beam 21 will be established at the "seaside".

– The side elements 8, 9 and top elements 10, 11 including working platforms 25 of the outer formwork are mounted, hence a complete formwork module 18 including reinforcements, ducts, prestressing boxes, etc. is established. Accordingly, the inner and outer formwork elements are joined together to form a relatively short, movable formwork module 18.

– New formwork modules 18 are built up in the same way and placed behind the first module (against support frame 20 and joined to the first module).

– After a sufficient number of formwork modules are built up, depending on the length of the inclined casting surface 26, the casting will be carried out by filling and/or pumping concrete through hatches 19 in the formwork. The lower halt of the tunnel will be filled by means of hatches in the inner formwork, and the upper halt will be filled through hatches in the outer formwork. After completion of the tilling operation, the hatches will be closed.

– During the concreting operation, new formwork modules will be assembled behind the last started module.

– When a suitable length is casted, the complete formwork including the tube is pulled a distance, equaling the length of a module, in the forward direction, whereby the front formwork module will be in a position above a demounting pit 30. The casting operation will continue independent of this operation.

– The front formwork module with cured concrete is demounted during lowering and transported to the rear end of the formwork by means of outer cranes and inner cranes 22. The formwork elements which are transported to the rear end are rebuilt to new formwork modules as earlier described.

– After the formwork elements are removed at the "seaside", cables are pulled in the embedded ducts and tightening of the prestressing cables in the cured part of the structure will be carried out from recesses 34 in the inner wall (see Fig. 3f). New cable lengths 35 will be connected to already prestressed cables 36, and thereafter tightened. After prestressing, the cable ducts 37 are grouted and the recesses 34 are closed by casting. The above described work is carried out on shore and under safe circumstances.

The described process is repeated and the submerged tube without joints is produced on shore in a continuous casting process and pulled step by step or continuously to its final position. Accordingly, the structure achieved full strength capacity in all parts without specific precautions.

The method is coat efficient, due to the fact that pulling (skidding) of the structure, concreting with the inclined casting surface and the prestressing operation can be carried out as independent operations.

The above example describes an apparatus in which six inner and six outer formwork elements are utilized, but an mentioned above, two inner and two outer formwork elements can be used. Further, instead of using inner/outer movable formwork elements, it is possible to utilize prefabricated tubes or tube sections which are mounted together to form a later permanent inner/outer lining of the structure. The preferred embodiment of the invention describes a circular, tube-shaped structure, however the method can be applied in constructing for example rectangular open semi-circular structures, etc.

Claims

1. A method for constructing a long span, substantially linear, reinforced, shell-shaped concrete structures having a front end and a rear end,

characterized in that the concrete structure is constructed in a continuous casting process by applying a substantially horizontal formwork apparatus with continuous supplying of fresh concrete with suitable consistency and by establishing, in relation to the horizontal plane, a free rearwardly inclining freely exposed casting surface (26), the method comprising the steps of applying a completely or partly displaceable and removable formwork unit (27) comprising a plurality of - in the operation mode - mutually joined formwork modules (18) which sequentially and repeatedly are moved from the front end (31) of the formwork to the rear end (33) of the formwork as the concrete structure together with the formwork unit (27) are moved forward in conformity with the curing speed of the concrete at the front end (31) of the formwork, until the complete concrete structure has achieved a desired length.

2. A method as claimed in claim 1, characterized in that each of the formwork modules (18) comprises a set of inner and a set of outer mutually joined formwork elements (6-17).

3. A method according to claim 2, in which the formwork modules (18) are supported on a base (23) which during the casting process can be moved stepwise or continuously in forward direction on a skid (24) or the like.

4. A method as claimed in claim 3, characterized in that the inner and the outer formwork elements (6-17) respectively, are supported independently of each other.

5. A method as claimed in any one of claims 2 to 4, characterized in that the inner and/or outer formwork elements comprises sections (6-17), some of which are repeatedly mounted and permanently embedded as an inner and/or outer lining of the structure.

6. A method as claimed in any one of claims 2 to 5, characterized in that the casting process is carried out according to the following steps:

(a) bottom elements (6, 7) of outer formwork of a formwork module (18) are mounted on a movable base (23),

(b) the bottom is reinforced, ducts for prestressing cables (37) and formwork for recesses are mounted,

(c) the inner formwork elements (12-17) including working platforms (25) of the module are mounted to a support beam (21) which is supported on a support frame (20) in the rear end (33) of the formwork unit and on a temporary support (28) at the front end (31), before the first part of the structure is cast and cured, thereafter on the completed and cured part of the concrete structure,

(d) reinforcement, ducts for prestressing cables (37) and formwork for recesses are mounted and completed,

(e) remaining formwork elements (8, 9, 10, 11) and working platforms (25) of the outer formwork are mounted, and the formwork module (18) is completed,

(f) filling concrete through hatches (19) in the formwork until the open space between the inner and the outer formwork is filled with concrete,

(g) demounting and removing the formwork modules (18) at the front of the cast structure when it has sufficiently cured, and transporting the formwork modules sequentially to the rear end (33) of the formwork for remounting,

(h) prestressing cables (35) are pulled in the embedded ducts (37) and connected to previously stressed cables (36) further back in the cured part of the structure,

(i) sufficiently cured concrete is exerted to compressive stresses by grouting the previously tightened cables, and access recesses (34) for the cables are filled with concrete,

(j) during this continuous process, the complete structure with and without formwork is sequentially moved in a forward direction, and the formwork process is repeated until the concrete structure has achieved the desired length.

7. An apparatus for carrying out the method as claimed in any one of the preceding claims, characterized by a number of bases (23) which are movable on a skid (24); a number of formwork modules (18) supported on the bases and connectable in-line, each formwork module comprising outer and inner formwork elements (6-17) provided with working platforms (25) and hatches (19) for the introduction of concrete, a support beam (21) including an inner crane rail (22) centrally located inside the formwork modules; and a demounting pit (30) for demounting the formwork modules sequentially.

8. An apparatus as claimed in claim 7, characterized in that the support beam (21) at the rear end (33) of the formwork unit is supported on a support frame (20) and at the front end (31) is supported on a temporary support (28) or on the inside surface of the completely cured concrete structure.

9. An apparatus as claimed in claim 7 or claim 8, characterized in that the skid (24) is mounted with

a downward and forward inclination.

10. A method for constructing a long span, substantially linear, reinforced, shell-shaped concrete structure having a front end and a rear end, characterized in that the concrete structure is constructed in a continuous casting process in which concrete is supplied to a substantially horizontal formwork unit (27) comprising a plurality of mutually connectable formwork modules (18) of which at least parts are sequentially and repeatedly moved from the front end (31) of the formwork unit to the rear end (33) of the formwork unit, the concrete structure together with the formwork unit (27) being moved forward as the concrete cures until the complete concrete structure has achieved a desired length.

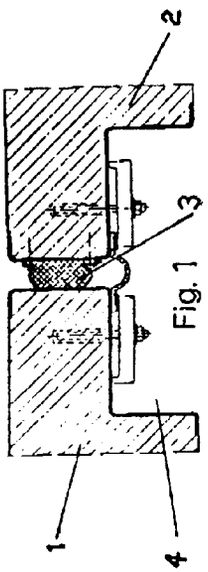

Fig. 1

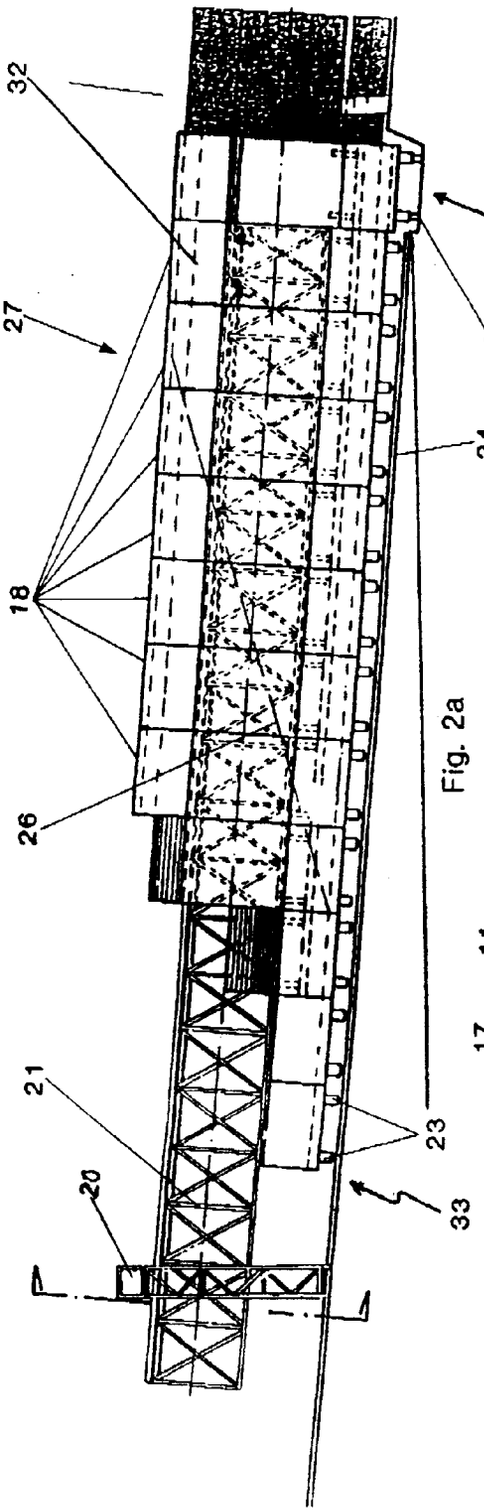

Fig. 2a

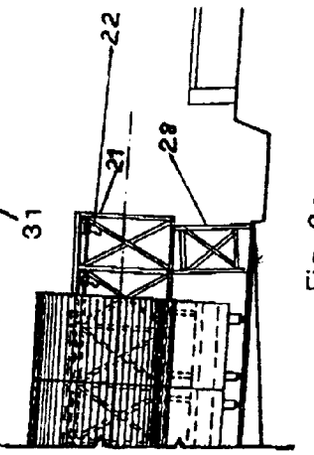

Fig. 2c

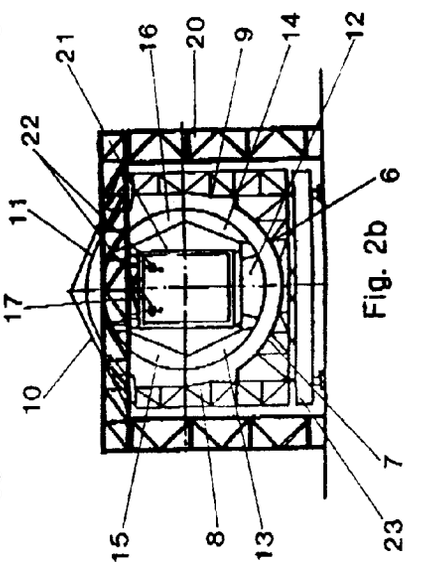

Fig. 2b

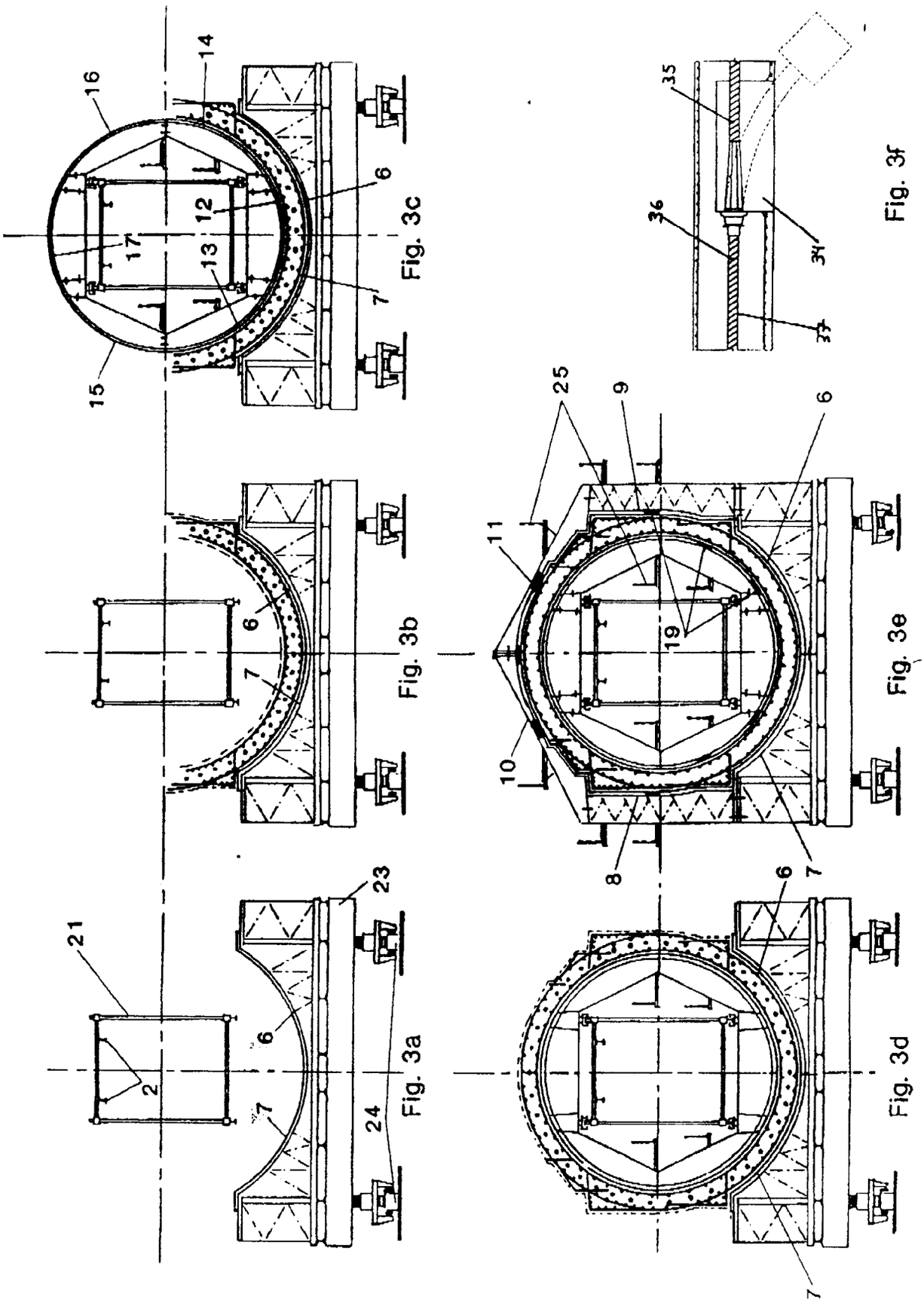
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Fig. 3a
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Fig. 3b
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Fig. 3c
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Fig. 3e
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Fig. 3d
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Fig. 3f

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EUROPEAN SEARCH REPORT

Application Number

EP 92 30 0692

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.5)
A	DE-A-2 135 867 (DYCKERHOFF & WIDMANN) * the whole document *	1	E01D21/04 E21D10/10
A	EP-A-0 278 078 (STRABAG BAU) * the whole document *	1,3	
A	DE-B-1 247 369 (HOLZMANN AG) * the whole document *	1	
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TECHNICAL FIELDS SEARCHED (Int. Cl.5)

E01D
E21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 APRIL 1992	DIJKSTRA G.

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