(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 001 089 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
17.05.2000 Bulletin 2000/20

(51) Int Cl.[7]: **E01D 19/14**, E01D 19/16

(21) Application number: **98119471.5**

(22) Date of filing: **15.10.1998**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: **Hou Yincheng**
41320 Göteborg (SE)

(72) Inventor: **Hou Yincheng**
41320 Göteborg (SE)

(54) Novel technique for stay cable system

(57) A stay cable system, which is exclusively for the tendons with parallel strands (I) covered by a sheath pipe (Ib), comprises main anchorage sockets (1), auxiliary anchorage sockets (2), anchoring tie beam (3), anchoring bed (4) that is used for girders other than steel I-girder or for pylon anchoring structure other than tie beam, dehumidification protection system (5a) - (5g).

Main features of the system are:

1) Anchoring holes in anchorage sockets (1, 2) are divided into two symmetrical groups (1a, 1b, 2a, 2b), so that main anchorage socket (1) can reliably be arranged at bottom part of any kind of girders holding cable axis coincided with girder web and double half-cylindrical auxiliary anchorage sockets (2) can be arranged on both sides of the web in steel I-girder (II), in anchoring tie beam (3) or in steel anchoring bed (4).

2) Based on the help of auxiliary anchorage sockets, in which parallel strands are anchored or bonded individually, ordinary jaws can reliably be used in main anchorage socket while individual strand replacement is allowable.

3) Dehumidification protection system keeps all parts of strands (I, Ia - not to be cut off after final jacking) under observable, controllable and reliable protected condition, which also facilitates individual strand replacement.

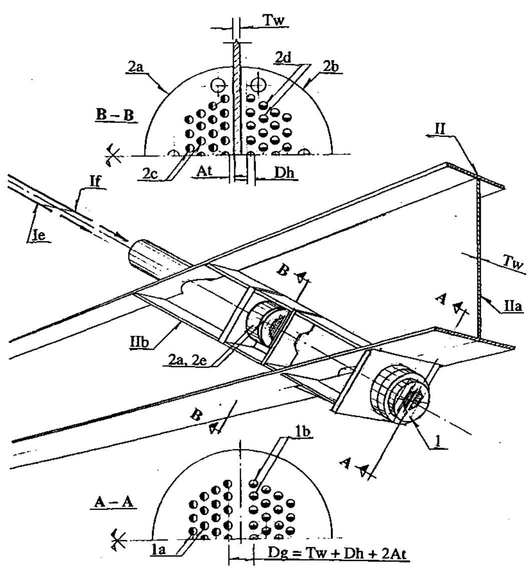

Figure 2. Novel arrangement of anchorage holes

EP 1 001 089 A1

Description

[0001] The invention relates to the field of stay cable system for cable-stayed bridges.

[0002] Stay cable system consists basically of tendon member, protection member, the member of anchorage sockets as well as the member of cable-girder and cable-pylon attaching structures. These members relate and influence with each other. Stay cables normally govern the useful life and construction progress of cable-stayed bridges with the following factors: resistance to fatigue loading and corrosion, ease of transportation and erection, allowance of inspecting as well as ability of eventual replacement. The attaching structures influence the safety, economy and aesthetics of whole bridge sensitively by the reliability and compact of their arrangement.

[0003] The tendons with parallel strands are more and more widely used in stay cable systems, because of their advantages of easy transportation and erection. But at present there are three serious problems in such kind of cable systems.

Problem A - anchorage socket.

[0004] Two types of anchorage socket are now currently used for such kind of cables:

1. In anchorage zone a grouted tube section, in which all strands are bonded together, is added to reduce the fatigue loading on normal strand jaws [Die Schrägkabelbrücke über den Mississippi bei Burlington, USA, H. Svensson and K. Humpf, Stahlbau 63(1994), Heft 7, p. 196, Fig. 8, 9]. Disadvantage of such kind of anchorage is that individual strand replacement is tremendously difficult to perform under cable service condition.
2. A special kind of jaws has been created to withstand both the static and fatigue load for anchorage. Therefor, individual strand replacement becomes much easier at any moment [Brochure: Freyssinet STAY CABLES May 1994, p.10 and 11, Fig.19]. But, the special jaws must be ensured by very high level of technology and quality control. Otherwise, big risk will be faced.

[0005] It is ideal to keep the ability of individual strand replacement while to avoid the necessity of extremely high strand jaws.

Problem B - corrosion protection.

[0006] At present the most current corrosion protecting method for such kind of cables is to cover the individual multilayer protected strands by a sheath pipe [Brochure: Freyssinet STAY CABLES MAY 1994 p.14, Fig.22], [Brochure: VSL STAY CABLE SYSTEM 200 SSI section "Corrosion Protection" and "Outer Stay Pipe"]. Easy to erect and replace strands is the main advantage of this method. But a great problem of the method is that if there is water and moisture inside sheath pipe, it is difficult to discover them and clear them away. It is necessary that water and moisture inside sheath pipe can be surveyed and cleared away.

Problem C - attaching structures.

[0007] In concrete cable-stayed bridges, web thickness of girder is usually bigger than diameter of cable anchorage head, so, cable anchorage socket is easy to go through the girder web and to be reliably anchored at the bottom of the girder. In composite cable-stayed bridges, web thickness of steel I-girder, which is the most economical type of steel girder, is much smaller than diameter of cable anchorage head, so, attaching structures become complicated. At present three imperfect types of attaching structure are normally used in composite cable-stayed bridges:

Type 1. Cable anchorage socket is arranged above bridge deck and anchored on a steel plate, which is welded to the top part of steel girder holding its axis coincided with girder web [Separate: Annacis Bridge Superstructure - A major composite cable-stayed bridge, P. R. Taylor, CBA - Buckland and Taylor consulting engineers Vancouver, B.C., December 6, 1985, Fig.2]. Main disadvantages of the structure are 1) large tensile and shear stress in weld and certain tensile stress in concrete deck. 2) Distance between damper and anchorage socket is too small, which reduces damper efficiency. 3) Cable can not be tensioned on girder site.

Type 2. Cable anchorage socket is arranged on one side of girder web and anchored at the lower part of girder on two stiffening steel plates that are welded to the girder web to avoid tensile force at top part of girder and to get sufficient distance between damper and anchorage socket [Separate: Cable-Stayed Houston Ship Channel Crossing, Holger S. Svensson and Thomas G. Lovett, Transportation Research Record No. 1290, Leonhardt, Andrä und Partner, p. 5, Fig. 7]. Basic disadvantage of the structure is that there is certain eccentricity between axes of cable and girder web, which forms additional moment in transverse beam and large stress in welds. Cable also can not be tensioned on girder site.

Type 3. Cable anchorage socket is arranged above bridge deck and anchored on two extended steel plates, which are welded or bolted to the bottom part of steel girder holding cable axis coincide with girder web and avoiding tensile force at top part of girder [Die Schrägkabelbrücke über den Mississippi bei Burlington, USA, H. Svensson and K. Humpf, Stahlbau 63(1994), Heft 7, p. 194, Fig. 4, 5, p. 197, Fig. 10]. Disadvantage of the structure is that the extended steel plates are heavy and bigger place occupied. Again, distance between damper and anchorage socket is too small and cable can not be tensioned on girder site.

[0008] Although arrangement of attaching structures in the stay cable system with parallel strands is easier to perform than that of other systems, the problem has still not been solved. It will be perfect if a light and handy way can be created to keep axes of cable and girder web in a same plane and to reliably arrange anchorage socket at bottom of steel I-girder.

[0009] This invention will solve the entire Problem A, Problem B and Problem C at the same time.

[0010] Figure 1 illustrates the general layout of the novel stay cable system, which is exclusively for the tendons with parallel strands (I) covered by a sheath pipe (Ib). The system comprises five parts:

1. Main anchorage socket (1).
Anchoring holes in the socket are divided into two symmetrical groups.
Axis of two symmetrical groups of strands (I) and the centre plane of web(s) of any kind of girders (II or IId) can coincide while the socket can be arranged under the bottom of the girders.
2. Auxiliary anchorage socket (2).
It comprises a pair of half-cylindrical anchorage sockets arranged on both sides of the web in steel I-girder (II), in anchoring tie beam (3) or in steel anchoring bed (4). In the sockets (2) strands can individually be anchored or bonded to withstand fatigue loading.
3. Anchoring tie beam (3) with I-section in pylon (III).
4. Steel anchoring bed (4) in pylon (III) instead of anchoring tie beam (3) as well as under the girders (IId) other than steel I-girder (II).
5.Cable protection system, which consists mainly of dry air entrances (5a), dry air transmission pipes (5b), dry air exits (5c) vent holes (5d), vent pipes (5e), wet air exits (5f) and dehumidification plant (5g).

[0011] Detail of each part is respectively described as follows.

Part 1 - novel arrangement of anchorage holes.

[0012] In current stay cable system with parallel strands, monostrand anchored holes on anchor head are normally arranged with odd number (for example 61). In this invention (see Figure2), monostrand anchored holes on main anchor head (1) are always arranged with even number (for example 60), and are separated into two symmetrical groups (1a and 1b). The minimum central distance Dg between the two groups of holes is Dg = Tw (thickness of web IIa of steel I-girder II) + Dh (diameter of monostrand anchored hole 2c and 2d in auxiliary anchorage sockets 2a and 2b) + 2At (thickness of inside wall of auxiliary anchorage sockets 2a and 2b). Thus, those two groups of strand (Ie and If) can easily pass through the I-girder (II) along both side of girder web respectively keeping axes of cable and girder web in a same plane then can reliably be anchored in a main anchor head (1) under the bottom of the girder (II). In pylon anchoring room, the strands (Ia) outside main anchorage socket (see Figure 1) do not be cut off after the final jacking, for it will be convenient for eventual individual strand replacement and the strands will be under protecting of dehumidification system (see Part 5).

[0013] Advantages of such arrangement are:

1) There is no eccentricity between axes of cable and girder web.
2) Approximately 60% of cable jacking force transfers directly to girder web by compression stress while the rest force transfers by four stiffening steel plates (3) and eight shear welds, very reliable.
3) Strands within the area of girder web and stiffening steel plates can be touched when cover plates (IIc, see Figure 3, 5) are removed, which facilitates strand erection, surveillance and replacement, furthermore, fatigue resistant facilities (left auxiliary anchorage socket 2a and right auxiliary anchorage socket 2b) can be arranged within this area (see the following part).
4) Cable can be tensioned on girder site, when necessary.
5) Distance between damper and anchorage socket is sufficient.

Part 2 - novel double half-cylindrical auxiliary anchorage sockets.

[0014] As mentioned above, within the area of girder web and stiffening steel plates, there is plenty of space to arrange fatigue resistant facilities - auxiliary anchorage sockets, which will help the main anchorage socket to withstand fatigue load (see Figure 2). Consequently, it becomes sufficiently safe to use ordinary jaws in main anchorage socket. Since auxiliary anchorage socket works for traffic load only, its construction ought and can be calmly arranged after the final cable force adjustment Besides the fatigue resistant criterion, another design criterion for auxiliary anchorage sockets is that strands must be individually anchored in the sockets to ensure the possibility of individual strand replacement. Two types of auxiliary anchorage socket are created for selecting.

1. Auxiliary anchorage socket 1.
Structure of the socket is showed in Figure 3 and Figure 4. In the socket there are auxiliary jaws (2j) with smaller bevel angle to anchor strands individually. Edge of teeth on auxiliary jaw is circular to

prevent injury and big stress concentration on the anchored strand (I).

1.1 Construction procedure of auxiliary anchorage socket 1 is:

1) Guide rails (2f) are erected and fixed on girder web (IIa).
2) Fastening plates ($2e_1$), on which auxiliary jaws (2j), nylon positioners (2k) and nylon washers (21) as well as fastening threaded bars (2h) have been fixed, auxiliary anchor heads ($2a_1$) and nuts (2i) are erected along the guide rails (2f) in proper order.
3) Main anchorage socket (1, see Figure 2) and strands (I) are erected, stressed and anchored.
4) When the final cable force adjustment has been done, triple cylinder hydraulic jacks (2m) are erected and then guide rails (2g) are fixed on stiffening plates (IIb) of girder.
5) Triple cylinder hydraulic jacks (2m) are driven to design force then nuts (2i) are tightened.
6) Triple cylinder hydraulic jacks (2m) are released and taken off together with guide rails (2g).
7) Cover plates (IIc) are erected and fixed onto stiffening plates (2b).

1.2 Procedure of eventual individual strand replacement of auxiliary anchorage socket 1 is:

1) Cover plate (IIc) is removed. Then nuts (2i) are released.
2) The strand, which should be replaced, is released by a single strand jack in pylon and removed.
3) A new strand is erected, stressed and anchored on main anchor head by a single strand jack. Then the procedure 4) to 7) aforementioned is repeated.

2. Auxiliary anchorage socket 2.

Structure of the socket is showed in Figure 5 and Figure 6. In the socket ($2a_2$) there are coned holes for each individual strands. Epoxy, zinc powder and quartz sand mixture (2q) is injected into the coned holes after the final tensioning of cable.

2.1 Construction procedure of auxiliary anchorage socket 2 is:

1) Guide rails (2f) are erected and fixed on girder web (IIa).
2) Isolation plates (2n), isolation plates (2o), auxiliary anchor heads ($2a_2$), fastening plates ($2e_2$), on which fastening threaded bars (2h) have been fixed and release agent (2t) has been smeared, isolation plates (2p) and nuts (2i) are erected along the guide rails (2f) in proper order.
3) Main anchorage socket (1, see Figure 2) and strands (I) are erected, stressed and anchored.
4) When the final cable force adjustment has been done nuts (2i) and isolation plates (2p) are tightened.
5) Epoxy, zinc powder and quartz sand mixture (2q) is injected into auxiliary anchorage sockets ($2a_2$) at grout hole (2r - in pylon) and (2s - under girder) until the mixture jets out from vent hole (2s - in pylon) and (2r - under girder). The mixture (2q) is then solidified in heating condition.
6) Cover plates (IIc) are erected and fixed onto stiffening plates (IIb).

2.2 Procedure of eventual individual strand replacement of auxiliary anchorage socket 2 is:

1) Cover plate (IIc) is taken off. Then nuts (2i) are released.
2) The strand, which should be replaced, is released by a single strand jack in pylon and by heating on the strand individually in both auxiliary anchorage sockets. At the same time fastening plate ($2e_2$) is pried open from auxiliary anchor head ($2a_2$). Then the strand is removed.
3) A new strand is erected, stressed and anchored on main anchor head by a single strand jack.
4) The mixture (2q) in grout holes (2s) is drilled away.
5) The nuts (2i) are tightened again while new mixture (2q) is injected into the coned hole through grout holes (2s). The new mixture is then solidified in heating condition.
6) Cover plates (IIc) are erected and fixed onto stiffening plates (IIb).

Part 3 - novel anchoring tie beam in pylon.

[0015] In order to arrange the double half cylindrical auxiliary anchorage sockets, anchoring tie beams in pylon (III) can be simplified to the most economical type of I-beam (3), web and stiffening plates of which are also signed with (IIa) (IIb) respectively as in I-girder. The structures mentioned in Part 1 and Part 2 are valid in Part 3. Tie beam with I-section can be extensively used for inclined cable plane by the helping of tie bars (3a) (see Figure 6). Advantages of the structure are:

1) Basic internal force in the structure is axial tension, which is totally withstood by the steel tie beams (3) and tie bars (3a), while no large moment and shear force happens.
2) Mass of pylon top can be reduced.
3) Operating space in pylon top becomes roomy in case of inclined cable plane.

Part 4 - novel steel anchoring bed.

[0016] In case the girders (IId) other than steel I-girder or the anchoring structures in pylon (III) other than tie beam are adopted and in order to arrange the double half cylindrical auxiliary anchorage sockets, the conventional anchoring bed can be replaced by a novel steel anchoring bed (4), web and stiffening plates of which are also signed with (IIa) (IIb) respectively as in I-girder (see Figure 8). The structures mentioned in Part 1 and Part 2 are valid in Part 4.

[0017] Compare with the conventional concrete anchoring bed, advantage of such anchoring bed is that it can simplify the form work of anchoring zone in concrete pylon, therefore mass of pylon top and construction period can be reduced.

Part 5 -- novel cable protection system.

[0018] Dehumidification system has been successfully used on Lillebaelt bridge since 1972. Now the system is being used on more and more bridges to protect steel box girders, saddles and anchoring blocks [Book: East Bridge, The Storebaelt Publications, 1998, P.374, 375]. Similar principle is adopted for this novel cable protection system (see Figure 9).

[0019] Two dry air transmission pipes (5b) are erected from the main anchorage plate (4a) in pylon (III) to the cells enclosed by stiffening plates (IIb) and cover plates (IIc) at the bottom of girder (II or IId) and connected to a dehumidification plant (5g), which is installed inside anchoring room at pylon top, by the dry air entrances (5a). When the dehumidification plant (5g) works, air circulates within the whole hollow part of cable. Dry air is blown into the transmission pipes (5b) through dry air entrances (5a), then separates out of dry air exits (5c) mainly at the bottom of sheath pipe (Ib), partly at the guide pipes (Ic) and cells enclosed by stiffening plates (IIb) and cover plates (IIc). At the same time wet air is exhausted out of cable to the plant (5g) through vent holes (5d), vent pipes (5e), which pass through the positioners (Id) of strands (I) in guide pipe (Ic), and wet air exits (5f). Such operation offers to one cable after another with certain hours per day or per couple of days for each cable. Similar operation offers also to anchoring room in pylon by dry air exit (5o) and wet air entrance (5p) of the plant (5g) at regular intervals to protect the strands (Ia) outside main anchorage socket (see Part 1 also).

[0020] Water concentrates usually at the lowest part of cable and moisture concentrates usually at the highest part of cable. Therefore, strand sample (5k) and humidity measuring point (5i) are arranged in the cells enclosed by stiffening plates (IIb) and cover plates (IIc) at the bottom of girder (II or IId), while strand sample (51) and humidity measuring point (5h) are arranged in the similar cells in pylon (III) respectively. Strand sample (5k) and/or strand sample (51) can be checked and tested in laboratory, when necessary. Similar checking and testing can be arranged for sample (5n) of the strands (Ia) outside main anchorage socket. Humidity measuring point (5h) can be connected to the automatic control system of dehumidification plant (5g), if necessary. If there is water inside hollow part of cable, it will flow down through drainage holes (5j) and can be pumped out through the drainage valve (5m).

[0021] Advantages of this cable protection system are:

1) Its obsevability, controllability and reliability are higher than those of the current cable protection systems are.
2) It is easy for replacing individual strand.
3) It is possible to simplify the individual strand protection (for example galvanised only).
4) If dehumidification plant can blow warm air into sheath pipe, will melt the ice on the pipe. So that it is possible to solve the problem of ice-wind-induced vibration on cable thoroughly.

Claims

1. A stay cable system (see Figure 1) exclusively for the tendons with parallel strands (I) covered by a sheath pipe (Ib) comprises five parts:

- Main anchorage socket (1), in which anchoring holes are divided into two symmetrical groups, can be arranged under any kind of girders (II - steel I-girder or IId - the girders other than steel I-girder) while cable axis and the centre plane of girder web(s) can coincide. In pylon anchoring room, the strands (Ia) outside main anchorage socket do not be cut off after the final jacking, for it will be convenient for eventual individual strand replacement and the strands will be under protecting of dehumidification system (see Part 5).
- Double half-cylindrical auxiliary anchorage sockets (2) are arranged on both sides of the web in steel I-girder (II), in anchoring tie beam (3) or in steel anchoring bed (4). In the sockets strands can individually be anchored or bonded to withstand fatigue loading and to facilitate eventual individual strand replacement. Based on the help of (2) ordinary jaws can reliably be used in main anchorage socket.

- Anchoring tie beams (3) with I-section in pylon (III) facilitates the arrangement of auxiliary anchorage sockets and extends its utilisation from vertical cable plane to inclined cable plane with the help of tie bars (3a).
- Steel anchoring bed (4) facilitates the arrangement of auxiliary anchorage sockets in pylon (III) instead of anchoring tie beam (3) as well as under the girders (IId) other than steel I-girder (II).
- Cable protection system, which consists of dry air entrances (5a), dry air transmission pipes (5b), dry air exits (5c) vent holes (5d), vent pipes (5e) wet air exits (5f), dehumidification plant (5g) as well as some other surveying, measuring, controlling and testing facilities, ensures strands under a observable, controllable and reliable protected condition.

2. A stay cable system as claimed in Claim 1, characterised in that the anchoring holes in main anchorage socket are divided into two symmetrical groups. The minimum central distance Dg between the two groups of holes is Dg = Tw (thickness of web IIa in steel I-girder II, in steel tie beam 3 with I-section or in steel anchoring bed 4) + Dh (diameter of monostrand anchored hole 2c and 2d in auxiliary anchorage sockets 2a and 2b) + 2At (thickness of inside wall of auxiliary anchorage sockets 2a and 2b), (see Figure 2, 7 and 8), to facilitate the arrangement of double half-cylindrical auxiliary anchorage socket (2).

3. A stay cable system as claimed in Claim 1, characterised in that the double half-cylindrical auxiliary anchorage socket (2) can withstand fatigue loading. Two types of auxiliary anchorage socket are created for selecting. In auxiliary anchorage socket 1 (see Figure 3,4) strands (I) are individually anchored by auxiliary jaws (2j), which can be released when individual strand replacement carries out, without injury and big stress concentration. In the coned holes of auxiliary anchorage socket 2 (see Figure 5, 6), strands (I) are individually bonded by epoxy, zinc powder and quartz sand mixture ((2q), which can be milted by heating when individual strand replacement carries out.

4. A stay cable system as claimed in Claim 1, characterised in that cable protection system consists of the members (5a) - (5g) as well as some other surveying, measuring, controlling and testing facilities. These facilities are: humidity measuring points (5h, 5i), drainage holes (5j), strand control and testing samples (5k, 5l) as well as drainage valve (5m) (see Figure 9). The similar members, dry air exit (5o) and wet air entrance (5p) of dehumidification plant (5g), as well as humidity measuring point (5n) are equipped to protect the strands outside main anchorage socket (see Figure 9). When the members (5a) - (5g) and (5o, 5p) operate, within all the hollow parts of cable and pylon anchoring room runs the air circulation, which is under the inspecting and controlling of facilities (5h) - (5n).

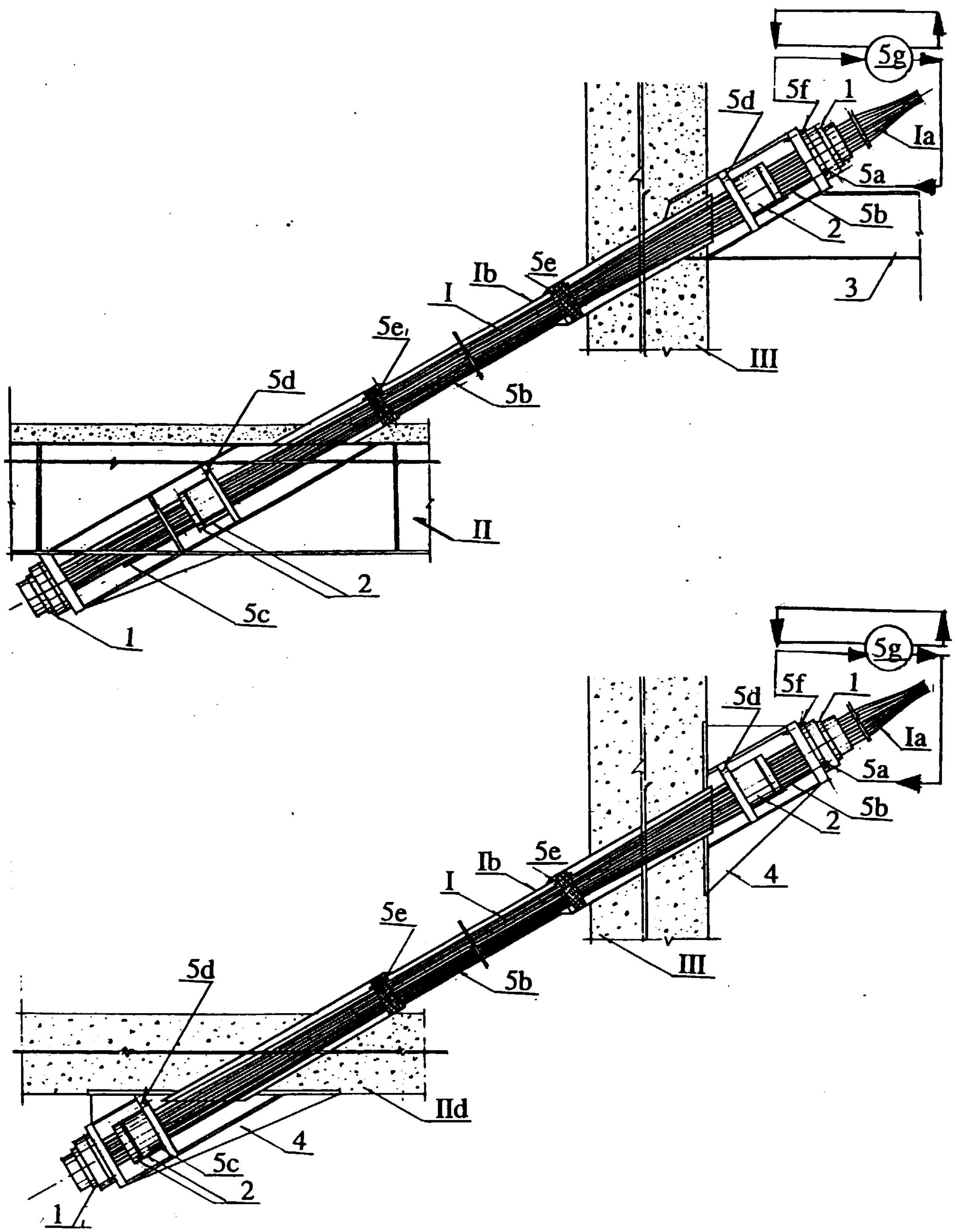

Figure 1. General layout of the novel stay cable system

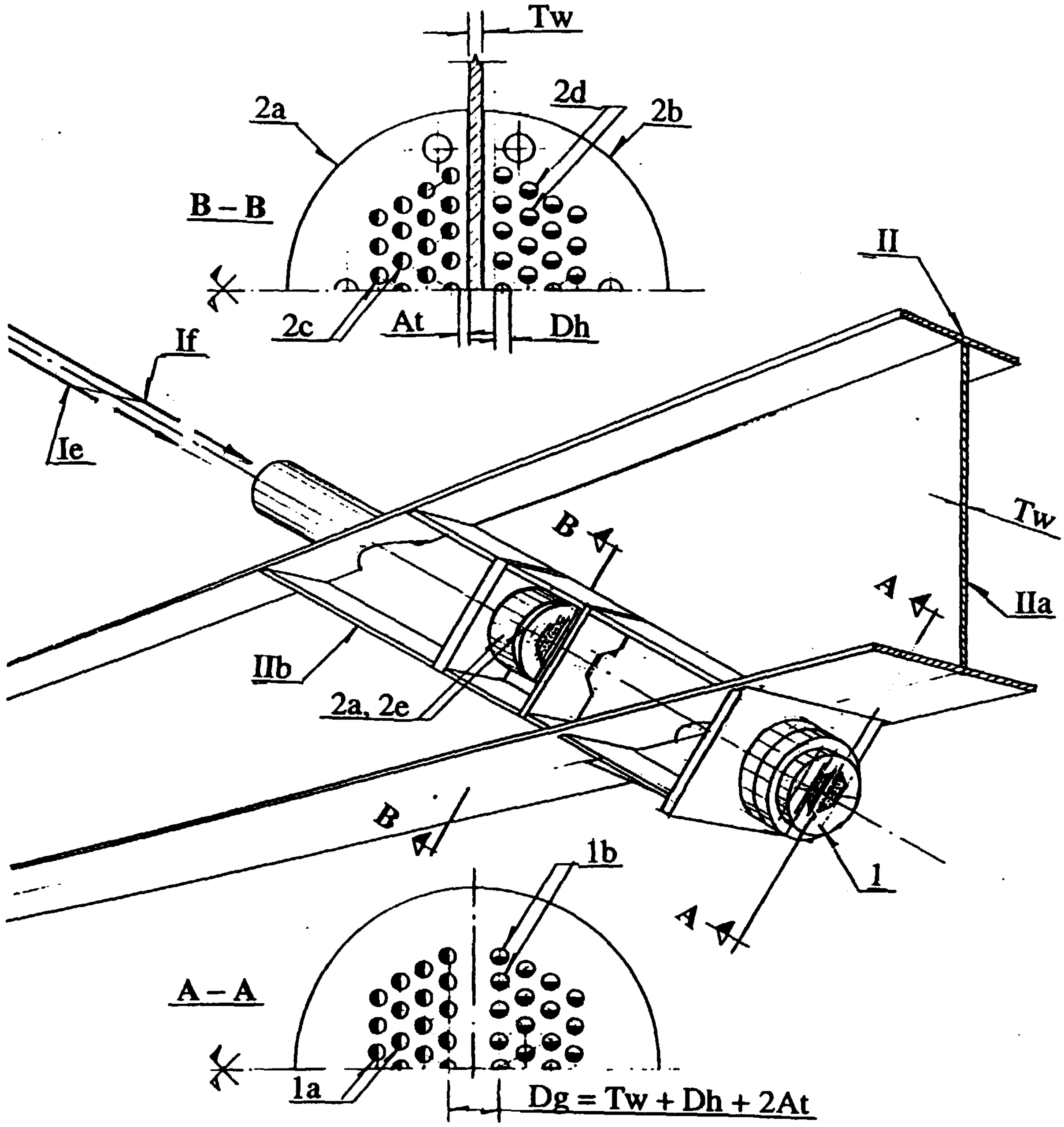

Figure 2. Novel arrangement of anchorage holes

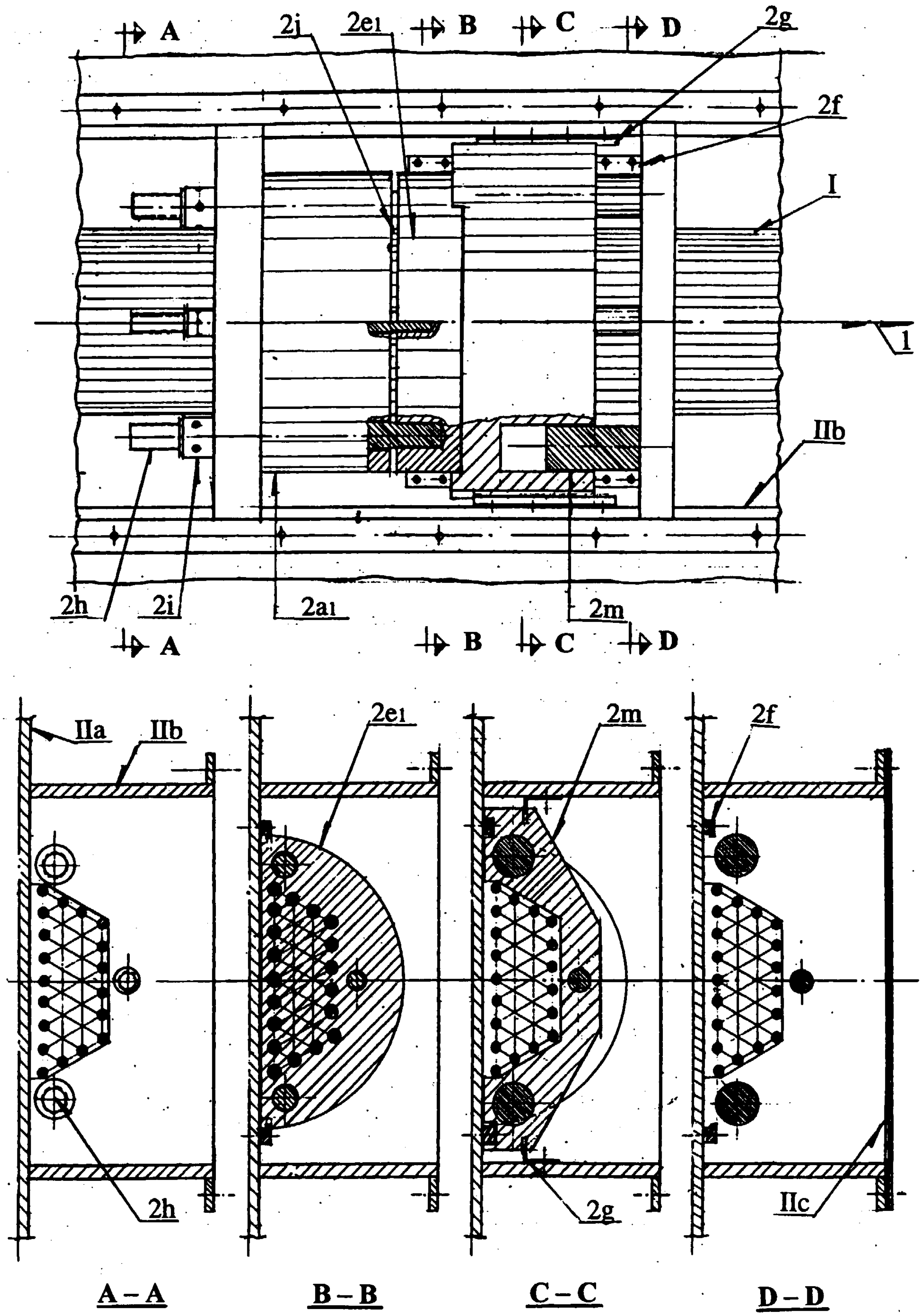

Figure 3. Auxiliary anchorage socket 1

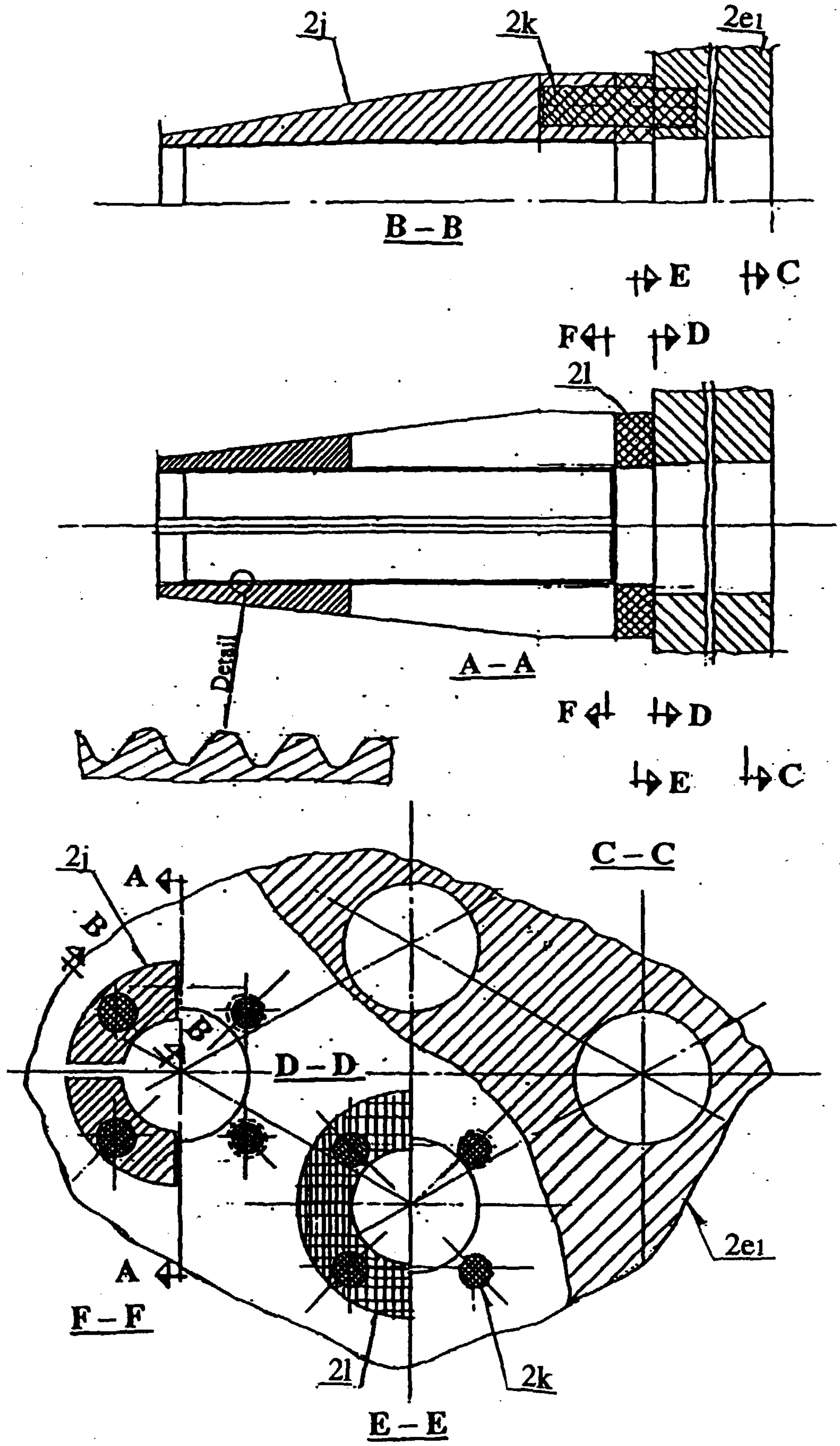

Figure 4. Detail of auxiliary anchorage socket 1

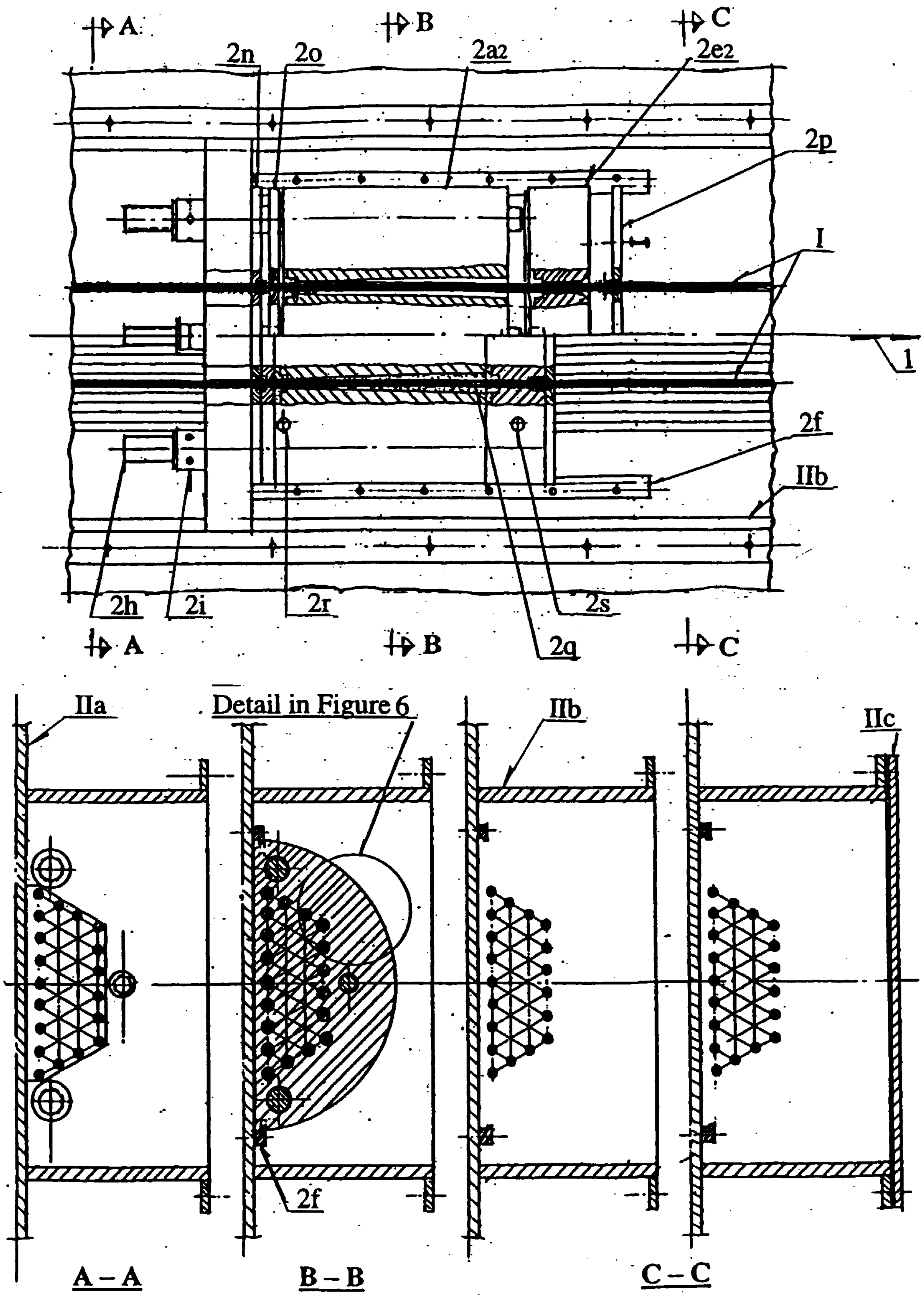

Figure 5. Auxiliary anchorage socket 2

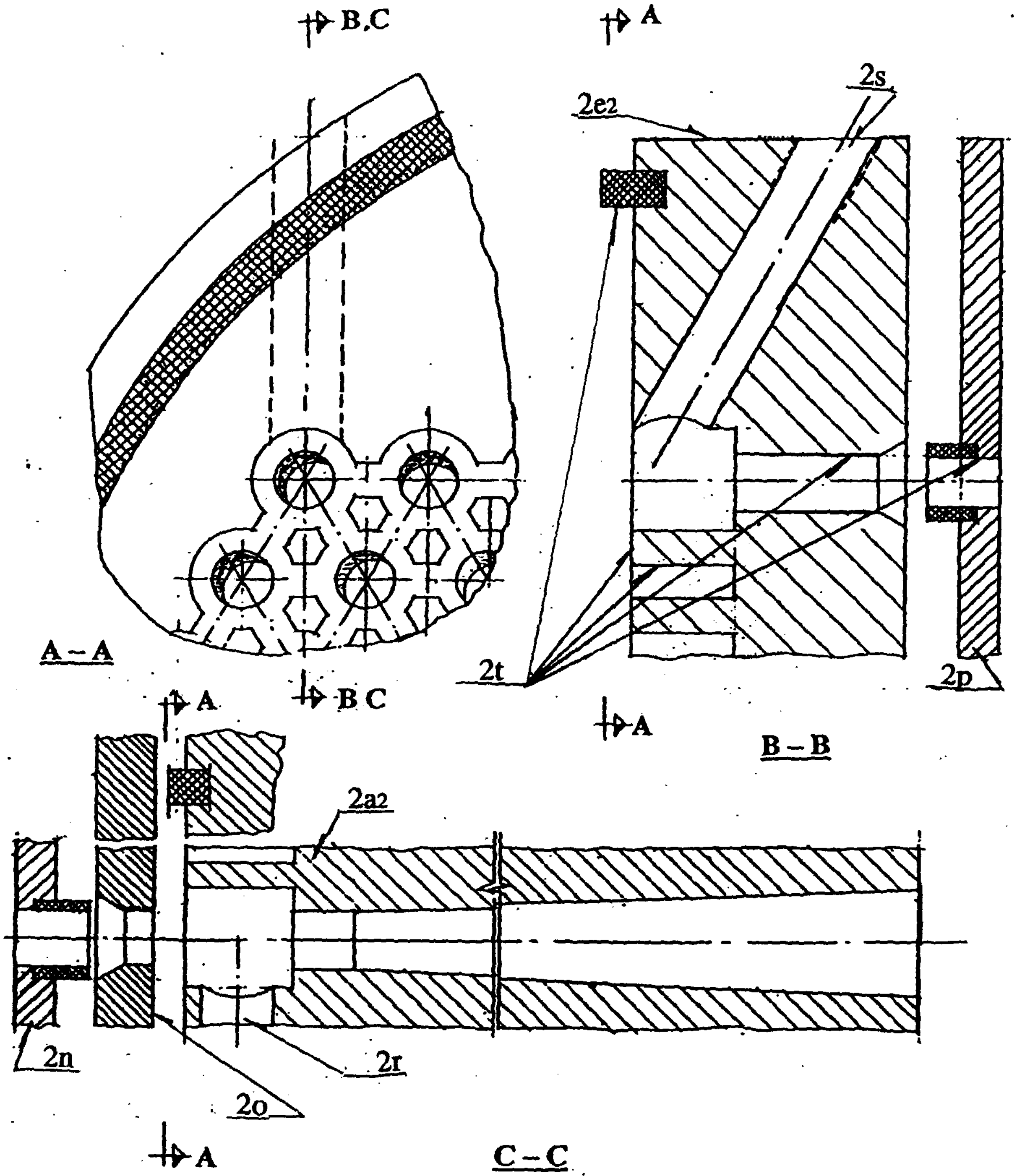

Figure 6. Detail of auxiliary anchorage socket 2

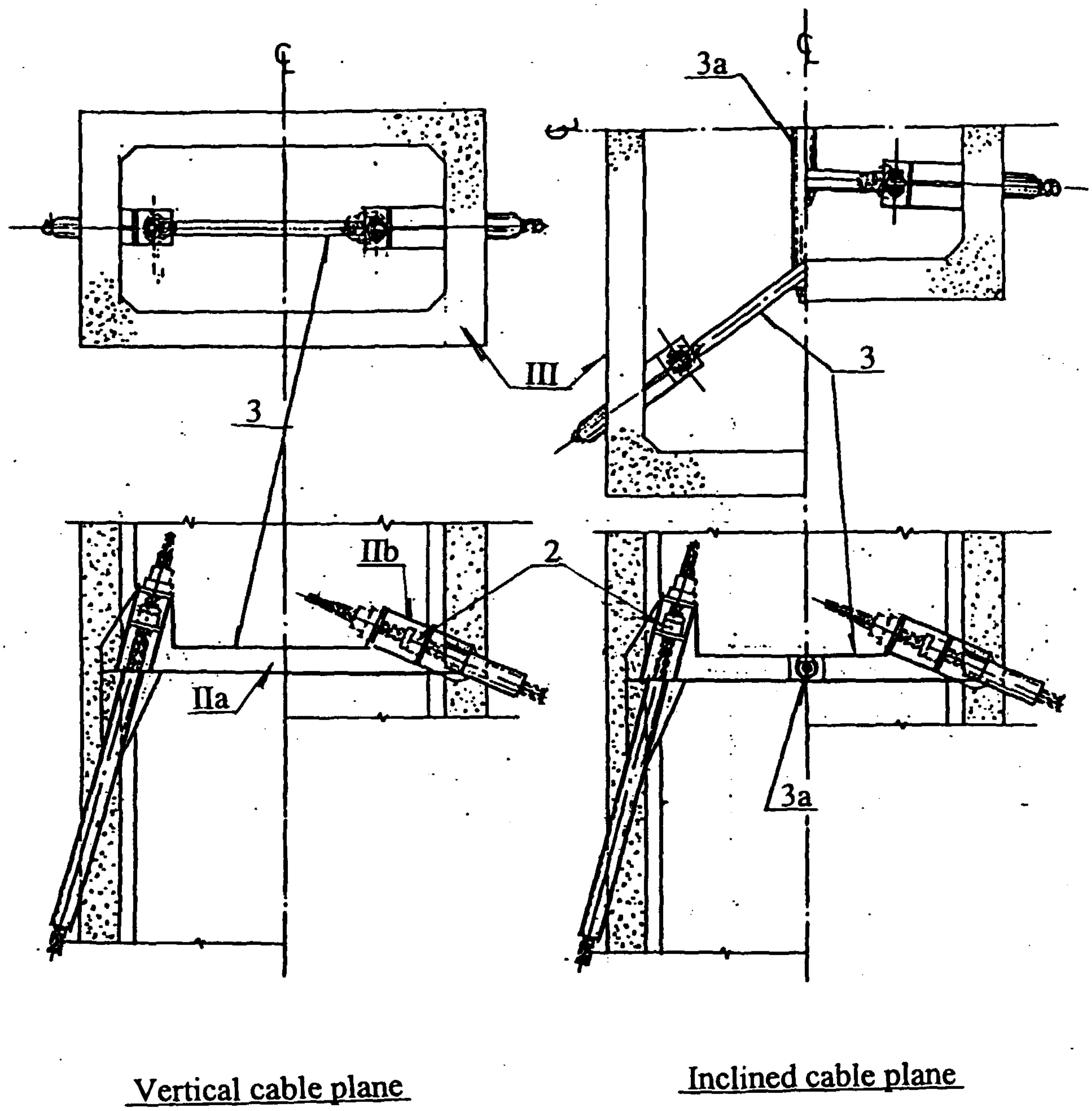

Figure 7. Novel anchoring tie beam in pylon

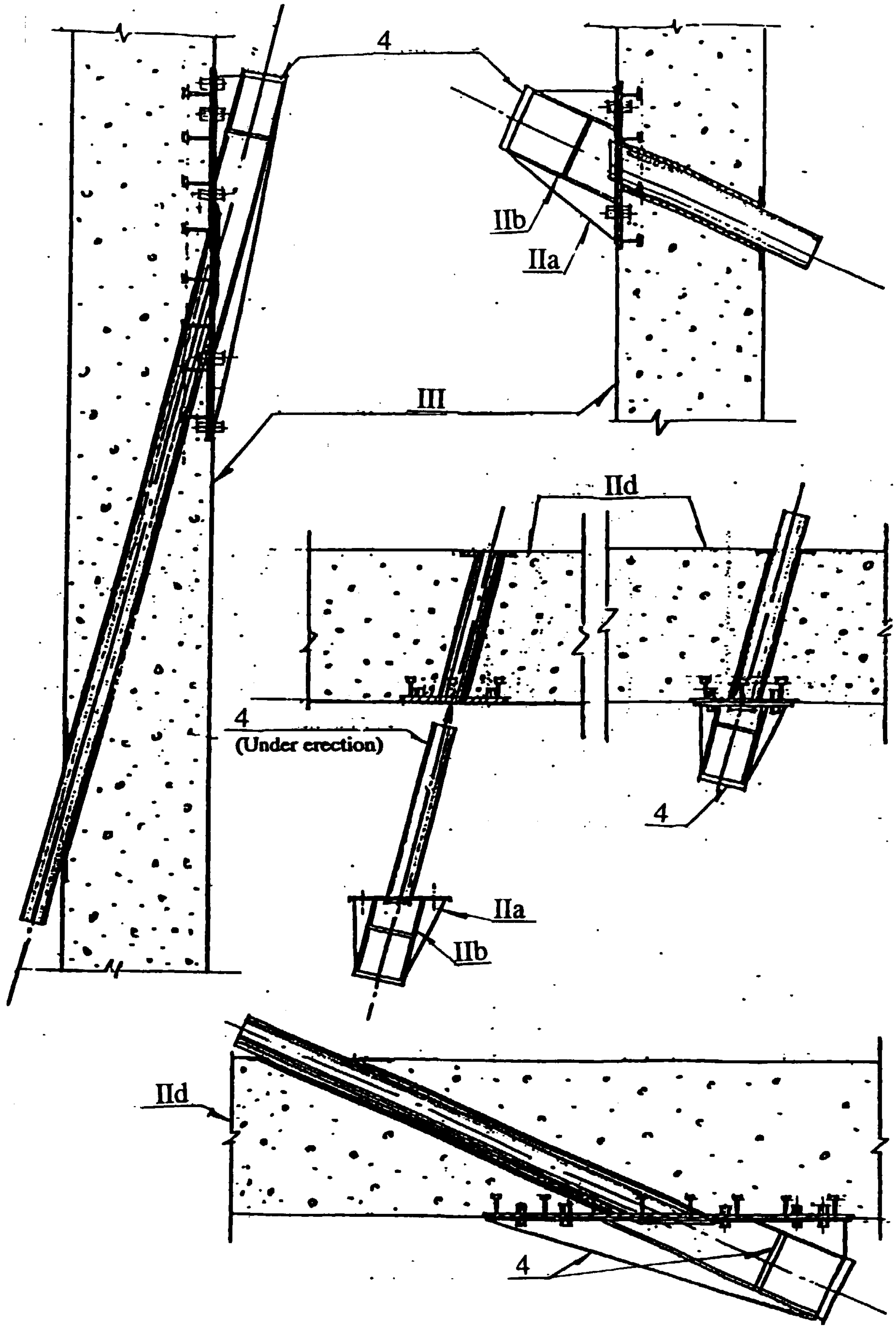

Figure 8. Novel steel anchoring bed

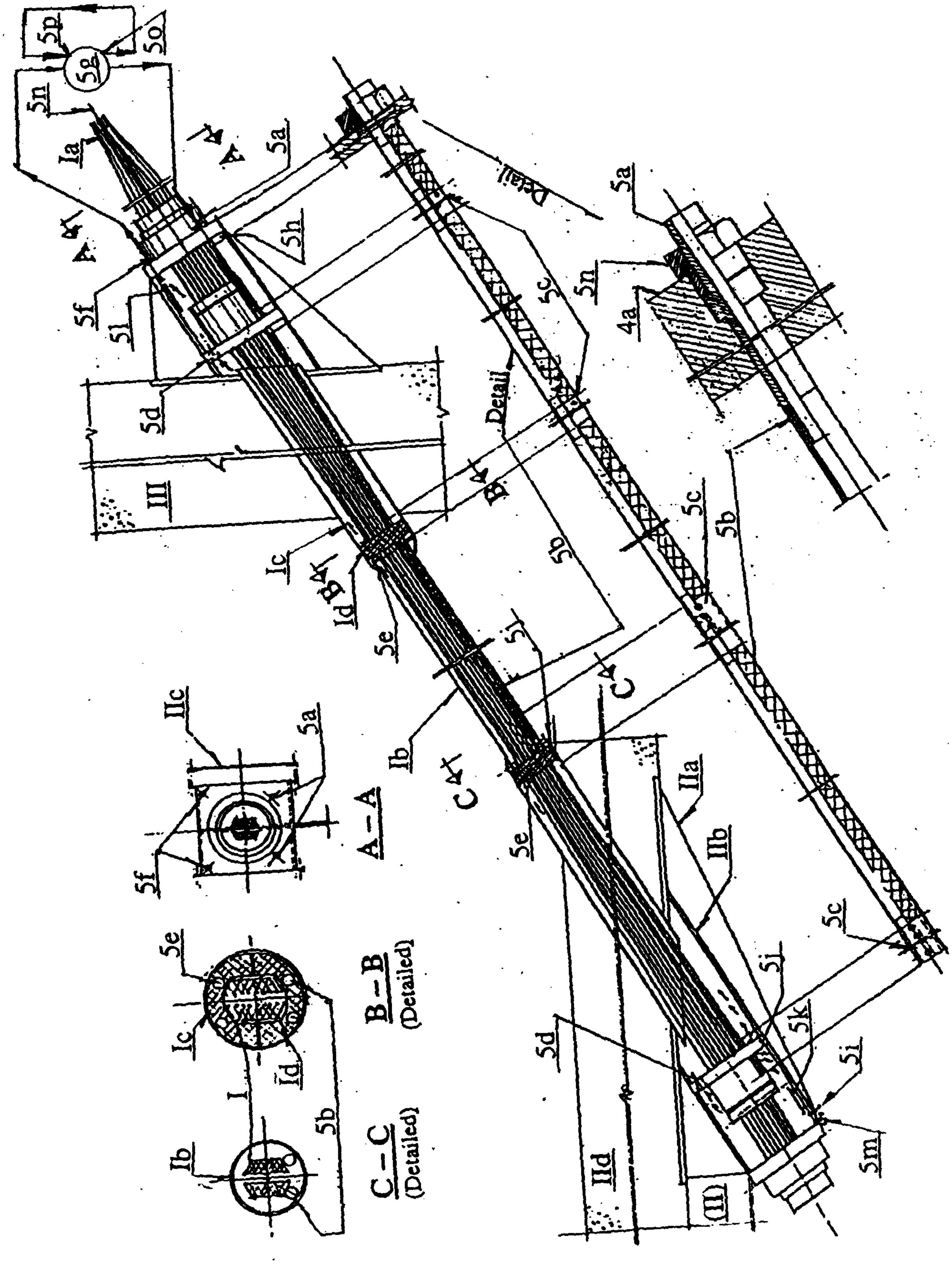

Figure 9. Novel cable protection system

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 11 9471

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)
A	DE 37 23 795 A (BORELLY WOLFGANG DIPL ING) 29 December 1988 * the whole document * ---	1,4	E01D19/14 E01D19/16
A	MONTENS S: "LE FRANCHISSEMENT DE L'ISERE PAR L'AUTOROUTE A 49" TRAVAUX, no. 666, 1 June 1991, pages 16-40, XP000216585 * figure 6 * ---	1	
D,A	SVENSSON: "Die Schrägkabelbrücke über den Mississippi bei Burlington,USA" STAHLBAU., vol. 63, no. 7, 1994, pages 193-197, XP002093577 BERLIN DE * figures * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			E01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	4 March 1999	Dijkstra, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 11 9471

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-03-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3723795 A	29-12-1988	AT 66708 T	15-09-1991
		DE 3864517 A	02-10-1991
		WO 8809847 A	15-12-1988
		EP 0354924 A	21-02-1990

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82