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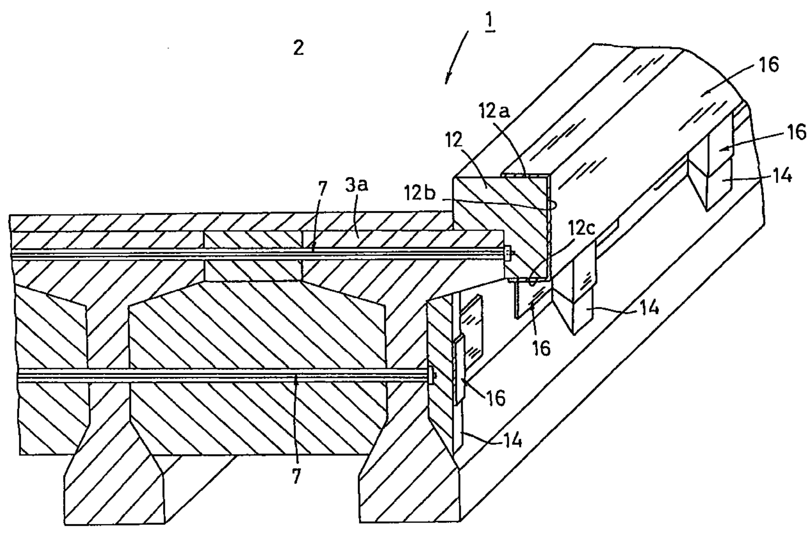
(54) **METHOD OF REPAIRING AND REINFORCING PRESTRESSED CONCRETE STRUCTURE**

(57) The present invention relates to a method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member such as PC steel. A reinforcing sheet (16) is secured to an end of a tension member disposed in a structure (1) or to a surface of a covering for the end to repair it whereby the end of the tension member is covered with the reinforcing material. With such arrangement, even when the tension member has been ruptured, the end of the protruded tension member is blocked by the reinforcing sheet to prevent the tension member from protruding outside the structure.



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Description

Technical Field

The present invention relates to a method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member such as PC steel (prestressed concrete steel), and more particularly to a method of repairing and reinforcing prestressed concrete structure in order to prevent the tension member from protruding unexpectedly from the structure as a result of rupture of the tension member such as PC steel.

Background Art

There has been used a measure of disposing a tension member such as PC steel for the application of prestress, since this measure is tolerable against the load applied to a concrete structure and is capable of preventing the concrete structure from cracking.

For example, a bridge beam having prestressed concrete structure which is tensioned by PC steel has generally a structure as illustrated in FIG. 9.

That is, several beams 3 each having a substantially T shape cross section are disposed in parallel relationship with each other, through which a sheath 2 laterally extends. Floor slab concrete 5 is cast between floor slabs 3a of the respective beams 3. A tension member 7 such as PC steel is inserted into the sheath 2, and then a jack or the like is attached to an end of the tension member 7 to pull the tension member 7, thereby applying a tension force thereto to tension the respective beams 3. Intermediate cross beams 8 are respectively cast with concrete between adjacent main beams 3b of beams 3, and are also tensioned by the tension member 7.

A reference numeral 10 represents a pavement applied on the floor slabs 3a, and a reference numeral 12 represents a curb provided by casting on outer edges of the floor slabs 3a as a cover to cover an ends of the tension member 7. A reference numeral 14 represents a cross beam covering made of concrete provided by casting on both sides the intermediate cross beam as a cover to cover an end of the tension member 7.

In accordance with the above post-tension construction, after the tensioning has been completed, grout is poured into clearances between the tension member 7 and the sheath 2 so that the tension member 7 become integral with a concrete structure 1.

However, in case of that the clearance has not been uniformly filled with grout, that is, in case of that there remains a clearance between the tension member 7 and the sheath 2, water may stay in such clearance to cause rust on the tension member 7. As a result, the rupture of the tension member 7 has recently taken place.

By such a rupture, the tension member 7 to which a tension force has been applied destroys the curb 12 and the cross beam covering 14, and then protrudes outwardly away from the concrete structure by an energy effected by abruptly releasing the tension member from the tensioned state. This protrusion of the tension member 7 is accompanied with an explosion.

Accordingly, not only the concrete structure loses the effect of prestress, but also there arise problems that the tension member 7 falls out of the sheath 2, and large broken pieces of the curb 12 and the cross beam covering 14 falls.

It is considered that there is a high possibility that particularly, prestressed concrete structure which was executed more than ten-odd years ago experience the above mentioned accidents, since a grout pouring technique was not so sufficiently advanced as the present technique.

It is the present state that any measures for preventing the tension member 7 from protruding outwardly are not applied to such existing structures and newly constructed structures.

Disclosure of Invention

The present invention has been made in consideration of the above conventional state. It is an object of the present invention to provide a method of repairing and reinforcing prestressed concrete structure in order to prevent the tension member from protruding unexpectedly away from the prestressed concrete structure.

In accordance with a method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member 7 such as PC steel, such object of the present invention is accomplished by securing a reinforcing sheet 16 to an end of the tension member 7 or to a surface of a covering for the end of the tension member 7.

When the reinforcing sheet 16 is secured to the end of the tension member 7 or the surface of the covering for the end of the tension member 7 as described above, the reinforcing sheet 16 absorbs an impact which is accompanied with an energy which is released as a result of the rupture of the tension member 7 (hereinafter referred to releasing energy), thereby preventing the tension member from protruding the outside.

In case of that the tension member 7 has the covering on the end thereof, broken pieces are generated due to the rupture of the tension member 7. However, the securing of the reinforcing sheet 16 also prevents the broken pieces from scattering outside.

Accordingly, it is unlikely that a person around the prestressed concrete structure is surprised at an unexpected protrusion of the tension member which occurs at an unknown time.

Further, the falling of the tension member which occurs as a result of the protrusion can be prevented.

In case of that the tension member is of a relatively elongated shape, or of a thicker shape, the releasing energy accompanied with the rupture of the tension member 7 becomes larger than that in a usual case.

In such case, it is also effective that an auxiliary steel plate 19 is secured to the end of the tension member 7 or to the surface of the covering for the end of the tension member 7, and the reinforcing sheet 16 is secured to the auxiliary steel plate 19.

That is, it is considered that the releasing energy accompanied with the rupture of the tension member comprises an impact destruction energy and kinetic energy effected by an initial impact.

Materials with an excellent shearing strength are preferable for the absorption of the impact destruction energy.

On the other hand, materials with an excellent tensile strength are preferable for the absorption of kinetic energy.

The auxiliary steel plate made of metal has an excellent shearing strength and is suitable for the absorption of the impact destruction energy.

Accordingly, for example, when the reinforcing sheet 16 adapted for being secured on the auxiliary steel plate 19 is made of a material with an excellent tensile strength, the absorption rate of kinetic energy increases.

Such combination of the reinforcing sheet 16 and the auxiliary steel plate 19 can effectively cope with the prevention of the protrusion of the tension member 7 with a relatively high releasing energy.

Further, it is also an effective measure that a plurality of the reinforcing sheets 16 which are made of a uniform material or different materials are secured, since the releasing energy is increased in case of that the tension member 7 is of a relatively elongated shape or that the tension force is larger, or in other cases, the outward protrusion of the tension member 7 may not sufficiently be prevented by securing one reinforcing sheet 16.

As a more specific measure, the reinforcing sheets 16 of different materials 16 are preferably constructed by a sheet of reinforced fiber with an excellent tensile strength and a sheet of reinforced fiber with an excellent shearing strength.

In case of that a sheet, which is made of such reinforced fiber with an excellent tensile strength such as carbon fiber, is impregnated and hardened with resin, and secured, such sheet becomes suitable for the absorption of kinetic energy.

On the other hand, in case of that a sheet, which is made of the reinforced fiber with an excellent shearing strength such as organic fiber including glass fiber, alamido fiber and polyolefine fiber, is impregnated and hardened with resin, and is secured, such sheet is suitable for the absorption of the impact destruction energy.

Accordingly, the protrusion of the tension member 7 with a higher releasing energy can effectively be prevented by securing plural sheets, which are respectively made from reinforced fibers of those different types.

It is also preferable that the reinforcing sheet 16 is made of a sheet, in which fabric, non woven fabric, prepreg sheet, or reinforced fiber is secured to a supporting member 17.

When the reinforcing sheet 16 is made of fabric, non woven fabric, prepreg sheet or reinforced fiber as described above, it is possible to form the reinforcing sheet 16 with a strength of such a degree as to prevent the protrusion of the tension member 7. Further, the securing of these materials to the supporting member 17 increases the strength of the reinforcing sheet 16, and prevents scattering of the fibers.

In case of that the reinforcing sheet 16 is made of prepreg sheet, the sheet hardens at ordinary temperature or hardens with heat in accordance with the composition of the resin included therein.

It is also preferable that the reinforcing sheet 16 is made of the reinforcing fibers forming one layer, in which the fibers are aligned in one direction, or the reinforcing fibers forming plural layers, in which the fibers are aligned in one direction or plural directions.

In case of preventing the protrusion of the tension member 7 by using the reinforcing sheet 16 with the reinforcing fibers aligned in one direction, a plurality of the reinforcing sheets 16 are usually secured in respective directions. On the contrary, in case of using the reinforcing sheet 16 of plural layers, in which the reinforcing fibers are aligned in different directions, it is advantageous in the fact that the reinforcement in different directions can equally be accomplished by a single sheet.

However, when comparing with the strength for one direction only, the sheet with the fibers aligned in different directions may have less amount of fibers as compared with the sheet with the fibers aligned in one direction.

In addition, it is also preferable that the reinforcing sheet 16 is made of reinforcing fibers, and the amount of reinforcing fibers per unit area is designed to be between 100 g/m^2 and 600 g/m^2.

The amount of the reinforcing fibers of the reinforcing sheet 16 is varied in accordance with the releasing energy when the tension member 7 has been ruptured.

However, the reinforcing sheet 16 having an extremely large amount of the reinforcing fibers per one sheet deteriorates the operation efficiency in securing the reinforcing sheet 16 and the impregnation property of the resin, and rises manufacturing cost and the like of the reinforcing sheet 16.

Accordingly, it is considered that the amount of the reinforcing fibers is preferably in the range of $100g/m^2$ to $600g/m^2$ for the reinforcing sheet 16 with the reinforcing fibers aligned in one direction.

However, when using non woven fabric, the reinforcing sheet 16 has an excellent impregnation property as compared with a cloth like sheet including one directional sheet and two directional sheet so that, even if the sheet having the reinforcing fibers of on or more than $600g/m^2$ is used, it may not adversely affect the operation efficiency or the like.

In case of that the reinforcing sheet 16 and the auxiliary steel plate 19 are secured via a bonding agent, the following effects can be produced:

When the tension member 7 has been ruptured, the reinforcing sheet 16 and the auxiliary steel plate 19 which have been pressed by the end of the tension member 7 are peeled off and then moved outward with a pressed portion as a center.

Accordingly, it is possible to find a ruptured portion of the tension member 7 by studying such a movement of the reinforcing sheet 16 from the outside.

As a result, it is possible to carry out the replacement of the ruptured tension member 7 in a secure manner, and maintain the strength of the prestressed concrete structure.

As another advantage, it is possible to prevent the scattering of the broken pieces of the structure produced by the rupture of the tension member by securing the reinforcing sheet 16 and the auxiliary steel plate 19 via the bonding agent.

When using a thermosetting resin as the bonding agent, which is capable of hardening at ordinary temperature, the following effect can be produced:

Since the bonding agent can spontaneously harden after the application thereof, the prestressed concrete structure can be repaired and reinforced in an extremely simple manner.

On the other hand, as a means for accomplishing the object of the present invention without using the reinforcing sheet 16, a reinforcing steel plate 20 may be secured to an end of the tension member 7 or to a surface of a covering for the end of the tension member 7 in a method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member 7 such as PC steel.

It is possible to prevent the protrusion of the tension member 7 by securing only the reinforcing steel plate 20 to the end of the tension member 7 or to the surface of the covering for the end of the tension member 7, in the same manner as in the case, where the reinforcing sheet 16 or the like is secured.

Further, the following effect can be produced by securing the reinforcing steel plate 20 via a bolt.

That is, even if the tension member 7 ruptures and then comes into collision with the reinforcing steel plate 20, the steel plate 20 is unlikely to remove from the prestressed concrete structure.

Accordingly, when the tension member 7 has come into collision with the reinforcing steel plate 20, a protrusion is generated in the reinforcing steel plate 20 by its impact so that the protrusion acts as a sign to find a ruptured portion of the tension member 7.

Accordingly, it is possible to find a ruptured portion of the tension member 7 from the outside of the structure.

Brief Description of Drawings

FIG. 1 is a perspective view illustrating a reinforcing sheet used in the first embodiment of a method of repairing and reinforcing prestressed concrete structure in accordance with the present invention.

FIG. 2 is a perspective view of an essential portion with a partial cross section illustrating an executed state of the method of the first embodiment.

FIGS. 3 illustrate an auxiliary steel plate used in the third embodiment of the method of repairing and reinforcing prestressed concrete structure, in which FIG. 3(A) is a plan view, and FIG. 3(B) is a side dew.

FIG. 4 is a cross section of an essential portion illustrating an executed state of the method in accordance with the third embodiment.

FIG. 5 is a perspective view illustrating another structure of the auxiliary steel plate used in the method of the third embodiment.

FIG. 6 is a perspective view illustrating a reinforcing steel plate used in the method in accordance with the fourth embodiment.

FIG. 7 is a front view of an essential portion illustrating an executed state of the method in accordance with the fourth embodiment.

FIG. 8 is a cross section of an essential portion illustrating a state that a tension member has been ruptured after the method of the fourth embodiment was executed.

FIG. 9 is a perspective view with a partial cross section illustrating a conventional prestressed concrete structure.

Best Mode for Carrying Out the Invention

The description will be made hereinafter, with reference to the drawings, for respective embodiments of a method of repairing and reinforcing prestressed concrete structure in accordance with the present invention.

Since prestressed concrete structure to which the method of the present invention is executed overlaps the prior art as mentioned above, the same reference numerals and the like will be used.

First embodiment

The first embodiment relates to a method, in which a reinforcing sheet is secured.

In FIG. 1, a reference numeral 16 represents a reinforcing sheet where unmeasured numbers of carbon fibers 18 as reinforcing fibers are aligned in one direction and in a plurality of layers on one surface of a supporting member 17.

The reinforcing sheet 16 is designed so that its amount of carbon fibers per unit area is 200 g/m^2, and tensile strength is 355 kg/mm^2.

It is not necessary to limit the supporting member 17 to a meshed shape, and it may be formed into a sheet. This supporting member 17 is provided to increase the strength of the reinforcing sheet 16 and prevent carbon fibers from scattering.

As illustrated in FIG. 2, the reinforcing sheet 16 is secured to a surface of a curb 12 of prestressed concrete structure 1 in such a manner as to cover an end of a tension member 7 which is made of PC steel. Specifically, primer is applied to a top surface 12a, a side surface 12b and a bottom surface 12c of the curb 12 to secure the adhering strength of resin.

After primer has been dried, thermosetting resin such as epoxy resin, which hardens at ordinary temperature, is applied as a bonding agent.

The reinforcing sheet 16 is then secured and a resin for finishing is applied thereon.

A second reinforcing sheet 16 is then secured in the same manner as the above. This reinforcing sheet 16 forming a second layer is secured in such a manner as to have carbon fibers thereof being substantially perpendicular to those of the reinforcing sheet 16 forming a first layer.

Even if the tension member 7 is ruptured, the outward protrusion of the tension member 7 is prevented by the reinforcing sheet 16 in the structure 1, to which the reinforcing sheet 16 has been secured.

Accordingly, it is unlikely that the tension member 7 falls out of the structure 1.

In this regard, the reinforcing sheet itself is not torn, but it is peeled off and moved outward with a portion pressed by the tension member as a center. As a result, broken pieces of the curb 12 accompanied by the rupture of the tension member 7 are confined between the reinforcing sheet 16 and the curb 12 so that they are unlikely to scatter outside.

In addition, it is advantageous in the fact that it is possible to detect from the outside that the outwardly moved portion of the reinforcing sheet 16 is a ruptured portion of the tension member 7.

It is a matter of course that the tension member 7 can also effectively act as reinforcement for concrete structure, even if the tension member 7 is not ruptured.

As illustrated in FIG. 2, it is a matter of course that the reinforcing sheet 16 is secured to a cross beam covering 14 in the same manner as the above.

(Test result)

The effects of the first embodiment were obtained based upon the following test.

As illustrated in FIG. 9, the structure 1, in which beam length A is 3,200 mm, top surface width B and side surface height C of the curb 12 are respectively 400 mm and 350 mm, height of a beam 3 having a substantially T shape in section is 1,000 mm, and diameter and length of the tension member 7 in the floor slab 3a are respectively 23 mm and 3,600 mm, was used as a test beam. Testing was conducted by applying a predetermined tension force (a ton of 26.9 lbs.) to the test beam, in which eight tension members 7 were disposed with equal spacing in the direction of beam length A (3,200 mm).

The testing objects are as follows:

(1) Two reinforcing sheets 16 made of carbon fibers of the first embodiment were superimposed to each other so that carbon fibers of the one reinforcing sheet 16 extend in the perpendicular direction to those of another reinforcing sheet 16. They were secured to cover 100 mm of the top surface 12a of the curb 12, the entire surface of the side surface 12b, 150 mm of the bottom surface 12c, and 1,600 mm of the curb 12 in the longitudinal direction of the beam.

(2) Three reinforcing sheets 16 made of glass fibers having a fiber amount of 215 g/m^2 and tensile force of 275 kg/mm^2 were superimposed to each other and secured to cover the same area of the curb 12 as the above.

(3) Two reinforcing sheets 16 made of alamido fibers having a fiber amount of 300 g/m^2 and tensile force of 350 kg/mm^2 were superimposed to each other and secured so that alamido fibers of the one reinforcing sheet 16 extend in the perpendicular direction to those of another reinforcing sheet 16.

The protruding state of the tension member 7 which was artificially ruptured was observed for each tested object.

The respective test results are as follows:

(1) Two reinforcing sheet of carbon fibers

The reinforcing sheets 16 were moved outward with a portion hit by the tension member 7 as a center in the area of 250 mm in the direction of the beam length A and 100 mm in the direction of the side surface height C.

However, there were not found any damages in the reinforcing sheets 16 themselves.

(2) Three reinforcing sheet of glass fibers

The reinforcing sheets 16 were torn with a portion hit by the tension member 7 as a center in the area of 350 mm in the direction of the beam length A, but the tension member 7 did not protrude outside.

(3) Two reinforcing sheet of alamido fibers

The reinforcing sheets 16 were slightly moved outward with a portion hit by the tension member 7 as a center in the area of 100 mm in the direction of the side surface height C.

However, there were not found any damages in the reinforcing sheets 16 themselves.

The effect of the method including securing the reinforcing sheets are based upon the test results as described above. However, a material of the reinforcing sheet 16 is not necessarily limited to carbon fibers as described in the first embodiment.

That is, the reinforcing sheet 16 may be made from glass fibers or alamido fibers used in the test. Instead, the reinforcing sheet 16 may be made from reinforcing fibers of organic fibers such as polyarylate fibers and polyolefine fibers.

Further, the reinforcing sheet 16 may be made from more than two types of fibers which are optionally selected from three types of the reinforcing fibers including carbon fibers, glass fibers and organic fibers. Further, the reinforcing sheet 16 may be made of fabric, non woven fabric, prepreg sheet or the like. It is essential that the reinforcing sheet 16 can be secured to the structure via a means such as a bonding agent, and is made of a material having the strength of such a degree as to prevent the protrusion of the tension member 7.

Accordingly, the amount of the reinforcing fibers, tensile strength and the like are not necessarily limited to the examples for carbon fibers and glass fibers as mentioned above, and can properly be varied.

Considering a degree of the simplicity in the execution, an impregnation tendency of the resin to the reinforcing sheet 16, the manufacturing cost of the reinforcing sheet 16, and the like, it is considered that the amount of the reinforcing fibers (excluding non woven fabric) is preferably in the range of 100 g/m^2 to 600 g/m^2, and tensile strength is preferably in the range of 100 kg/mm^2 to 1,000 kg/mm^2.

In the above embodiment, the reinforcing sheet 16 is constructed so that reinforcing fibers are aligned in one direction and in a plurality of layers. However, it is not necessary to limit the reinforcing sheet 16 to such construction. For example, the reinforcing sheet 16 may be made of a sheet with one layer of reinforcing fibers aligned in one direction, or a sheet with plural layers of reinforcing fibers which is made by layering plural groups of the reinforcing fibers aligned in a predetermined direction so that the reinforcing fibers are aligned in different directions in a plurality of layers.

In addition, in the method of the above embodiment, two reinforcing sheets 16 are superimposed to each other and are secured in order to increase the strength. However, it is not necessary to arrange the reinforcing sheets 16 in two layers.

That is, the reinforcing sheet 16 may be arranged in one layer provided that it can prevent the protrusion of the tension member 7. It is a matter of course that more than the reinforcing sheets 16 may be arranged in more than two layers.

In the above embodiment, two reinforcing sheets 16 are secured so that the fibers of one reinforcing sheet extend in the substantially perpendicular direction to those of another reinforcing sheet 16. However, it is not necessary to limit the extending direction of the reinforcing sheets 16 to the perpendicular direction.

For example, two or more reinforcing sheets 16 may be secured so that the fibers extend in the same direction.

Thus, the quality, construction, amount of fibers, strength, securing area, and the like of the reinforcing sheet 16 may properly be varied in accordance with the scale of the structure, diameter and length of the tension member 7, manufacturing cost, executing cost, and the like.

It is essential that the reinforcing sheet 16, which can do no less than prevent the protrusion of the tension member 7, is properly selected in accordance with a surrounding condition.

In addition, the reinforcing sheet 16 which can display a phenomenon such as the outward movement thereof at the time of the rupture of the tension member 7 is preferable, since it is possible to confirm from the outside whether there is the rupture of the tension member 7. The rupture of the reinforcing sheet 16 can be confirmed via visual observation in accordance with the degree of such outward movement, once the reinforcing sheet 16 has been moved outward. As a more securing manner, it is possible to confirm from the outside, whether there is the rupture of the tension member 7, by judging a hollow portion generated inside of the reinforcing sheet 16 as a result of the outward movement of the reinforcing sheet 16, in which the hollow portion can be judged in accordance with a sound produced by hitting the surface of the reinforcing sheet with a hammer or the like.

Second embodiment

The second embodiment relates to a method, in which the reinforcing sheets of different materials are secured in a plurality of layers.

In this embodiment, the reinforcing sheet 16 with alamido fibers aligned in one direction is secured to the surface of the curb 12 of the prestressed concrete structure 1 in such a manner as to cover an end of the tension member 7 in the same execution method as that in the first embodiment.

The reinforcing sheet 16 with carbon fibers aligned in one direction is, then, secured to the reinforcing sheet of alamido fibers so that the reinforcing sheet 16 of alamido fibers is covered therewith, in which the carbon fibers are aligned in a substantially perpendicular direction to that of the alamido fibers.

The reinforcing sheet 16 of alamido fibers which has been impregnated to the resin and hardened, has an excellent shearing strength and is suitable for absorbing impact destruction energy.

The reinforcing sheet 16 of carbon fibers which has been impregnated to the resin and hardened, has an excellent tensile strength and is suitable for absorbing kinetic energy.

By superimposing the sheet of reinforcing fibers having an excellent tensile strength to the sheet of reinforcing fibers having an excellent shearing strength and securing them, the advantages of the respective fibers are obtainable at the same time. Thereby, it is possible to prevent the protrusion of the tension member 7 with a higher energy, as compared with the arrangement that the reinforcing sheets 16 of a uniform material are superimposed to each other and secured.

(Test result)

The effects of the second embodiment was obtained based upon the following test.

As illustrated in FIG. 9, the structure 1, in which beam length A is 3,200 mm, top surface width B and side surface height C of the curb 12 are respectively 400 mm and 350 mm, height of the beam 3 having a substantially T shape in section is 1,000 mm, and diameter and length of the tension member 7 in the floor slab 3a are respectively 23 mm and 3,600 mm, was used as a test beam. Testing was conducted by applying a predetermined tension force to the test beam, in which eight tension members 7 were disposed with equal spacing in the direction of the beam length A (3,200 mm).

As a testing object, two reinforcing sheets 16 each having alamido fibers aligned in one direction are secured to the surface of the curb 12 of the prestressed concrete structure 1 one by one in such a manner as to cover an end of the tension member 7 by the same execution method as in the first embodiment, and direct alamido fibers of one reinforcing sheet 16 in the substantially perpendicular direction to those of another reinforcing sheet 16. Two reinforcing sheets 16 each having carbon fibers aligned in one direction are, then, secured one by one on the reinforcing sheet 16 of alamido fibers so that carbon fibers of one reinforcing sheet 16 extend in the substantially perpendicular direction to those of another reinforcing sheet 16.

The protruding state of the tension member 7 which was artificially ruptured was observed.

As a result, the reinforcing sheets 16 were moved outward with a portion hit by the tension member 7 as a center in the area of 200 mm in the direction of the beam length A and 100 mm in the direction of the side surface height C.

However, there were not found any damages in the reinforcing sheets 16 themselves.

Third embodiment

The third embodiment relates to a method, in which an auxiliary steel plate and the reinforcing sheet are secured.

In FIGS. 3A and 3B, a reference numeral 19 represents an auxiliary steel plate which is formed into a disk shape with a peripheral edge 19a which is rounded by taper-cutting.

The auxiliary steel plate 19 with a thickness of 3.2 mm is used.

The material, structure, numbers and the like of the reinforcing sheets 16 to be secured are selected from those described in the first and second embodiments.

As illustrated in FIG. 4, the auxiliary steel plate 19 is secured via a bonding agent to a surface of the curb 12 of the structure 1, which surface lies on an extension line of the tension member 7.

A difference in level generated in the surface of the curb 12 by the reinforcing steel plate 19 is, then, leveled by using epoxy resin 23 or the like. The reinforcing sheet 16 is then secured in a proper manner. In this regard, it is preferable to take the following points into consideration.

In case of securing the reinforcing sheet 16, it is necessary to insure a sufficiently larger securing area of the reinforcing sheet 16 to the surface of the curb 12 as compared with the securing area of the auxiliary steel plate 19. The reason for this will be described below:

If the securing area of the reinforcing sheet 16 to the surface of the curb 12 is narrower, the reinforcing sheet 16 is likely to be peeled off from the surface of the curb 12 by kinetic energy produced at the time of the rupture of the tension member 7, with the result that the reinforcing sheet 16 cannot sufficiently display its tensile force.

With such arrangement where the reinforcing sheet 16 is secured on the auxiliary steel plate 19, an impact produced by the protrusion of the tension member 7, can be absorbed at first by the auxiliary steel plate 19.

Accordingly, it is advantageous in the fact that the protrusion of the tension member 7 can be prevented, even if the reinforcing sheet 16, which has a relatively weaker strength as compared with that in the first embodiment, is used.

The auxiliary steel plate 19 having an excellent shearing strength is suitable for absorbing impact destruction energy.

Accordingly, the use of the reinforcing sheet 16 of a material having a relatively excellent tensile force (e.g., carbon fibers) can effectively cope with the repairing and reinforcing of the structure, in which the releasing energy accompanied by the rupture of the tension member 7 is higher than that in a usual case, for example, the structure with a lengthy tension member 7 and being subjected to a larger tension force,

In addition, the auxiliary steel plate 19 secured via the bonding agent is moved outward by the protrusion of the tension member 7 as a result of the rupture so that the presence of the rupture can be observed from the outside.

(Test result)

The effects of the third embodiment was obtained based upon the following test.

As illustrated in FIG. 9, the structure 1, in which beam length A is 3,200 mm, top surface width B and side surface height C of the curb 12 are respectively 400 mm and 350 mm, height of the beam 3 having a substantially T shape in section is 1,000 mm, and diameter and length of the tension member 7 of the floor slab 3a are respectively 23 mm and 3,600 mm, was used as a test beam. Testing was conducted by applying a predetermined tension force to the test beam, in which eight tension members 7 were disposed with equal spacing in the direction of the beam length A (3,200 mm).

As a testing object, the auxiliary steel plate 19 of the third embodiment, which has a diameter of 200 mm and the peripheral edge 19a which has a rounded shape formed by taper cutting, was secured via resin to the surface of the curb 12 of the prestressed concrete structure 1 in such a manner as to cover an end of the tension member 7 in the same manner as in the first embodiment. Two reinforcing sheets 16 each having carbon fibers aligned in one direction were secured one by one to the auxiliary steel plate 19 so that carbon fibers of one reinforcing sheet 16 extend in the substantially perpendicular direction of those of another reinforcing sheet 16.

The protruding state of the tension member 7 which was artificially ruptured was observed.

As a result, the reinforcing sheets 16 were moved outward with a portion hit by the tension member 7 as a center in the area of 250 mm in the direction of the beam length A and 250 mm in the direction of the side surface height C.

However, there were not found any damages in the reinforcing sheets 16 themselves.

In the third embodiment, the auxiliary steel plate 19 having a disk shape was proposed as an example. However, it is not necessary to limit the auxiliary steel plate 19 to such shape. For example, the auxiliary steel plate 19 may be of a rectangular shape or other shapes. It is essential to construct the auxiliary steel plate 19 from a plate like member with a suitable thickness.

In the third embodiment, the auxiliary steel plate with a thickness of 3.2 mm was proposed as an example. However, it is not necessary to limit the auxiliary steel plate 19 to a thickness of 3.2 mm. A thicker auxiliary steel plate 19 is not always suitable for this application, since it is difficult to manufacture the auxiliary steel plate 19 in accordance with the shape of the structure to which the auxiliary steel plate 19 is secured, as the thickness increases. The welding operation or the like also becomes hard to be done. Further, the presence of the rupture can not be observed from the outside, since deformation of the auxiliary steel plate 19 does not occur at the time of the collision.

On the other hand, when the auxiliary steel plate 19 is too thin, it cannot cope with impact destruction energy, with the result that the tension member 7 passes through the auxiliary steel plate 19 and then protrudes the outside.

When consideration is given to the above by comparing these thickness with each other, it is considered that the thickness of the auxiliary steel plate 19 is preferably in the range of 0.1 mm to 10 mm.

Fourth embodiment

The fourth embodiment relates to a method, in which only a reinforcing steel plate is secured.

In FIG. 6, a reference numeral 20 represents a reinforcing steel plate 20 which has an engaging portion 20a being formed into a substantially U shape and mounting portions 20b, 20b extending from the opposite ends of the engaging portion 20a to be engaged with the cross beam covering 14. A pair of holes 21, 21 are formed in the respective mounting portion 20b, 20b. The reinforcing steel plate 20 has a thickness of 6 mm.

As illustrated in FIG. 7, the reinforcing steel plate 20 is engaged with the surface of the cross beam covering 14 of the prestressed concrete structure 1 in such a manner as to cover an end of the tension member 7. Bolts 22 are respectively inserted into the holes of the mounting portions 20b to boltholes (not shown) formed in the main beam 3b. Nuts 23 are respectively threadably secured to the tip portions of the bolts 22 protruding from the opposite side of the main beam 3b, thereby securing the reinforcing steel plate 20 to the main beam 3b.

As illustrated in FIG. 8, when the tension member 7 has been ruptured, the reinforcing steel plate 20 prevents the tension member 7 from protruding outside, thereby preventing large broken pieces of the tension member 7, the cross beam covering 14 or the like from falling.

When the end of the tension member 7 has come into collision with the reinforcing steel plate 20, the engaging portion 20a is curved outwardly to form a protruded portion. Thus, it is possible to observe from the outside whether there is the rupture of the tension member 7. That is, the presence of the rupture of the tension member 7 can be observed via the protruded portion of the reinforcing steel plate 20 without using any tools, apparatuses and the like.

(Test result)

The effects of the fourth embodiment was obtained based upon the following test.

As illustrated in FIG. 9, a test beam of an actual size, in which beam width D of the structure is 4,000 mm, a width E of the cross beam covering 14 is 200 mm, height of the beam 3 having a T shape in section is 1,000 mm, and diameter and length of the tension member 7 in the intermediate cross beam 8 are respectively 23 mm and 3,000 mm, was used.

As illustrated in FIG. 6, the protruding state of the tension member 7, which was artificially ruptured, was observed for two types of the reinforcing steel plates 20 as a testing object which respectively have 6 mm and 12 mm in thickness, length H of 300 mm, width I of 460 mm, depth J of 85 mm at the engaging portion 20a.

The results for the respective testing objects are shown below.

(1) Reinforcing steel plate with a thickness of 6 mm

The protrusion of the tension member 7 was prevented, and the surface of the reinforcing steel plate 20 was curved. Accordingly, the presence of the rupture of the tension member 7 could be observed from the outside as described above.

(2) Reinforcing steel plate with a thickness of 12 mm

The protrusion of the tension member 7 was prevented. However, a change of the reinforcing steel plate 20 could not be visually observed. Accordingly, the presence of the rupture of the tension member 7 could not be visually observed from the outside.

The reinforcing steel plate 20 having a thickness of 6 mm in the fourth embodiment was determined based upon the test result. However, it is not necessary to limit the reinforcing steel plate 20 to a thickness of 6 mm, since the reinforcing steel plate having a thickness of 5 mm or 7 mm also produces the same effect as the effect produced by the reinforcing steel plate 20 with a thickness of 6 mm. In addition, even if the reinforcing steel plate 20 with a thickness of 12 mm is used, it is possible to obtain the effect that at least the protrusion of the tension member 7 can be prevented.

Accordingly, the thickness of the reinforcing steel plate 20 can be varied in accordance with the shape and scale of the structure, the length and diameter of the tension member 7, etc.

That is, the thickness, area, material or the like of the reinforcing steel plate 20 in the fourth embodiment can properly be varied in accordance with the scale of the structure, the diameter of the tension member 7 or the like, since the reinforcing steel plate 20 with a thickness of, for example, 3 mm may prevent the tension member 7 from protruding the outside, and accomplish the confirmation of the presence of the rupture of the tension member 7 from the outside in accordance with the scale of the structure.

However, when consideration is given to the scale of the existing structure, the length of the tension member 7 used in the structure, the limit of the manufacturing technique for the reinforcing steel plate 20, cost, etc., it is considered that the thickness of the reinforcing steel plate 20 is preferably in the range of 1 mm to 15 mm.

It is a matter of course that several reinforcing steel plate 20 each having a thickness of, for example, 3 mm can lay on top of the other to form the reinforcing steel plate 20 with a thickness of 6 mm, 9 mm or more.

<u>Other embodiments</u>

As an example of the arrangement where an end of the tension member 7 is covered, the arrangement where the curb or the cross beam covering is provided is proposed in the respective embodiments. However, the method of the present invention can be carried out for a portion where an end of the tension member 7 is exposed to the outside without the curb or the cross beam covering.

In the third embodiment, the auxiliary steel plate 19 is formed by one plate. However, it is possible to form the auxiliary steel plate 19 to have a thickness of, for example, 3 mm by forming several steel plates each having a thickness of 1 mm into a predetermined shape and superimposing to each other.

Claims

1. A method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member such as PC steel, characterized by that a reinforcing sheet (16) is secured to an end of a tension member (7) or a surface of a covering for the end of the tension member.

2. A method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member such as PC steel, characterized by that an auxiliary steel plate (19) is secured to an end of a tension member (7) or a surface of a covering for the end of the tension member, and a reinforcing sheet (16) is secured on said auxiliary steel plate (19).

3. A method of repairing and reinforcing prestressed concrete structure as set forth in claim 2, wherein the auxiliary steel plate (19) has a thickness of 0.1 mm to 10 mm.

4. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein a plurality of the reinforcing sheets (16) of one type or different types are secured.

5. A method of repairing and reinforcing prestressed concrete structure as set forth in claim 4, wherein the reinforcing sheets (16) of different types comprise a sheet of reinforcing fibers having an excellent tensile strength and a sheet of reinforcing fibers having an excellent shearing strength.

6. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein the reinforcing sheet comprises a sheet, in which fabric, non woven fabric, prepreg sheet or reinforcing fiber is secured to a supporting member.

7. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein the reinforcing sheet (16) is made from reinforcing fibers, and the reinforcing fibers are aligned in one direction and in one layer, or the rein-

forcing fibers which are aligned in one direction or different directions, and a plurality of layers.

8. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein the reinforcing sheet (16) is made from at least one of glass fibers, carbon fibers and organic fibers, each of which having a tensile force of 100 kg/mm^2 to 1,000 kg/mm^2.

9. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein the reinforcing sheet (16) is made from reinforcing fibers, and an amount of the reinforcing fibers per unit area is in the range of 100 g/m^2 to 600 g/m^2.

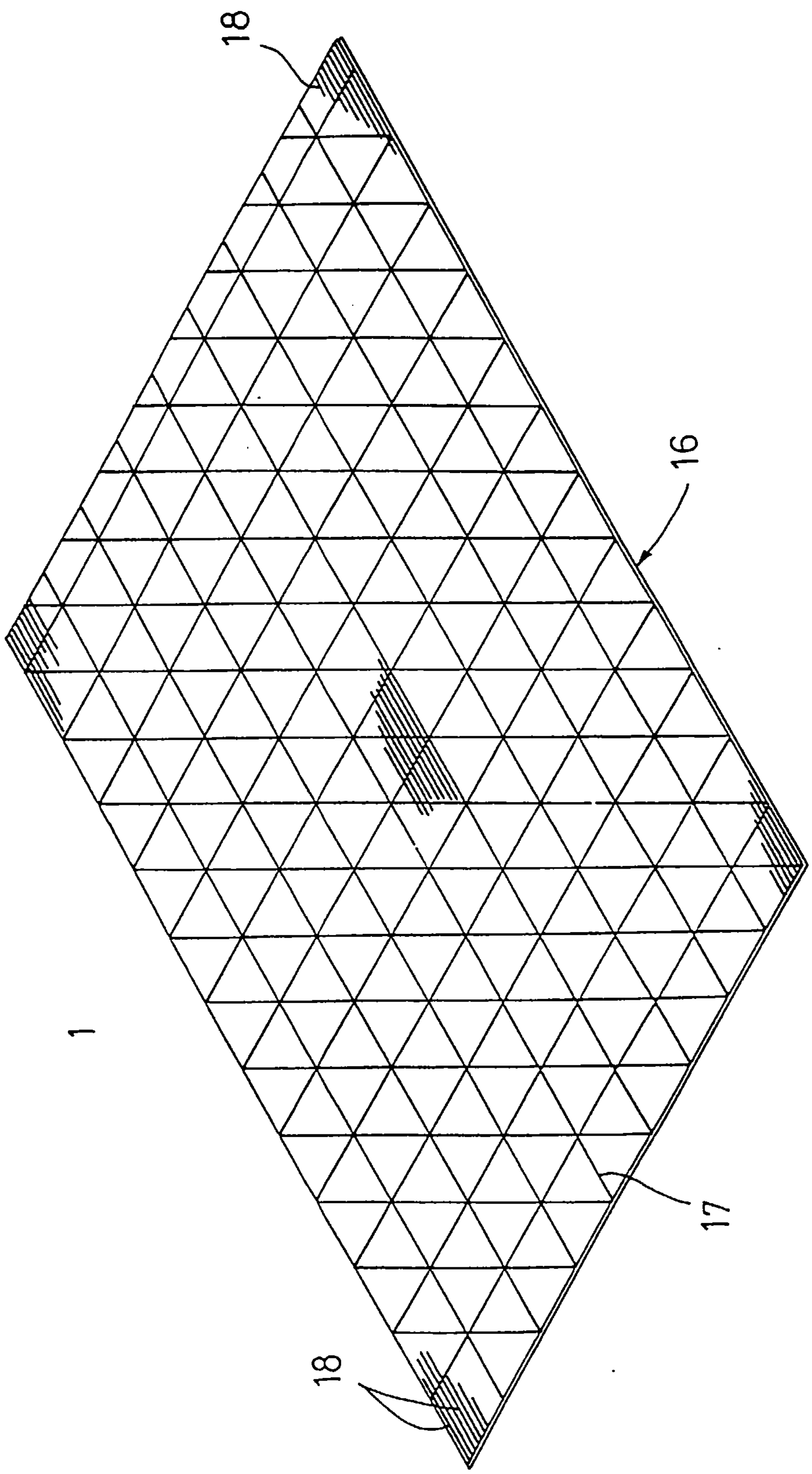
10. A method of repairing and reinforcing prestressed concrete structure as set forth in any one of claims 1 and 2, wherein the reinforcing sheet (16) is secured to the auxiliary steel plate (19) via a bonding agent.

11. A method of repairing and reinforcing prestressed concrete structure as set forth in claim 10, wherein the bonding agent is a thermosetting resin which can harden at ordinary temperature.

12. A method of repairing and reinforcing prestressed concrete structure which is applied prestress by a tension member such as PC steel, characterized by that a reinforcing steel plate (20) is secured to an end of a tension member (7) or a surface of a covering for the end of the tension member.

13. A method of repairing and reinforcing prestressed concrete structure as set forth in claim 12, wherein the reinforcing steel plate (20) is secured via a bolt.

14. A method of repairing and reinforcing prestressed concrete structure as set forth in claim 12, wherein the reinforcing steel plate (20) has a thickness of 1 mm to 15 mm.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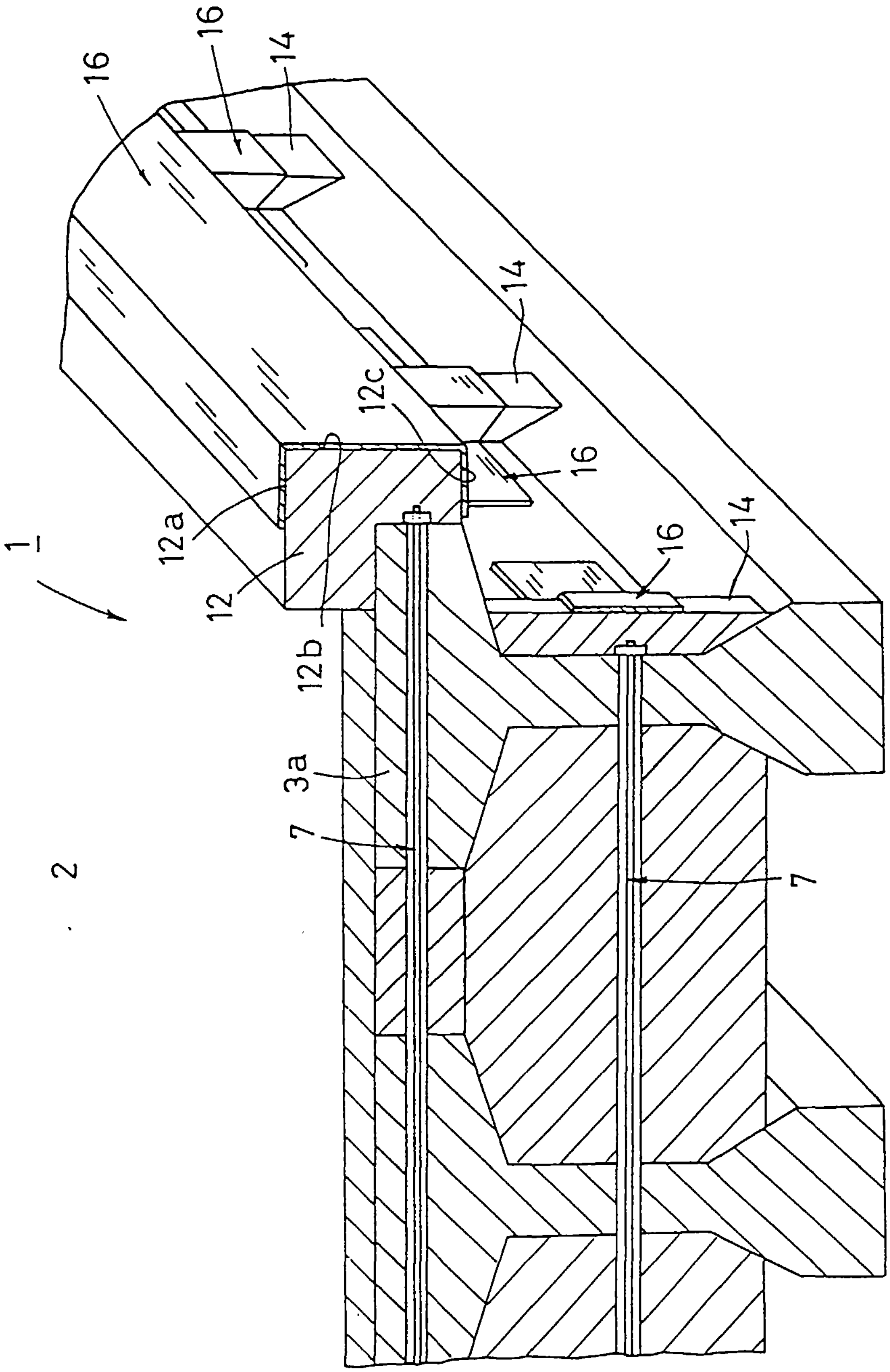
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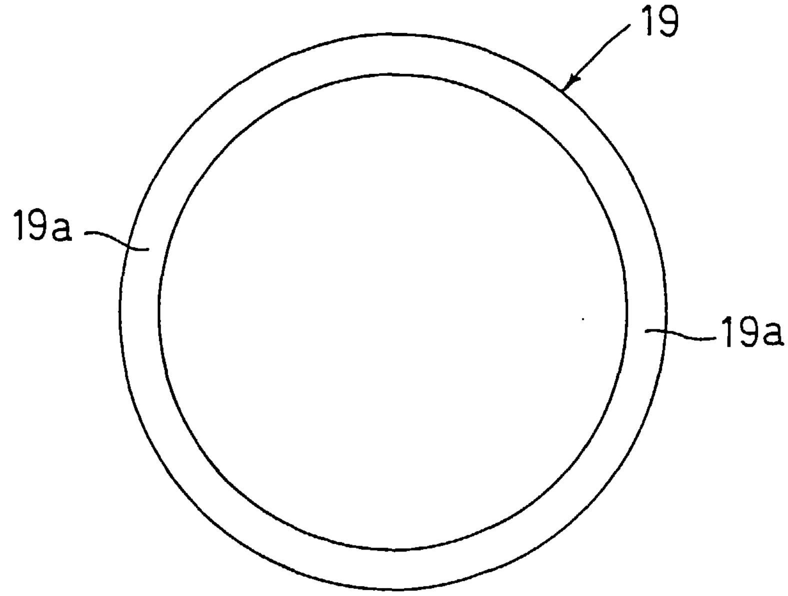

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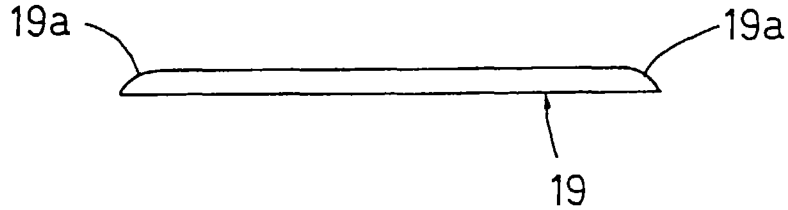

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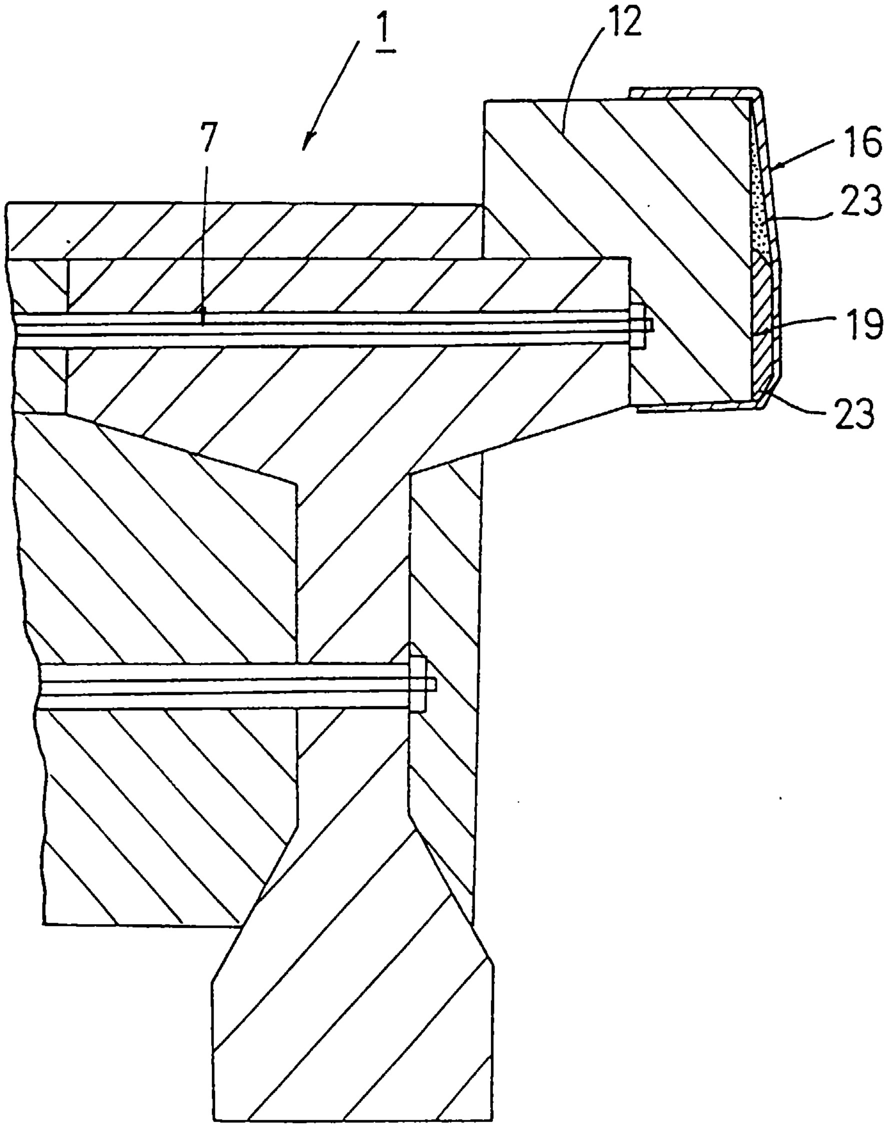

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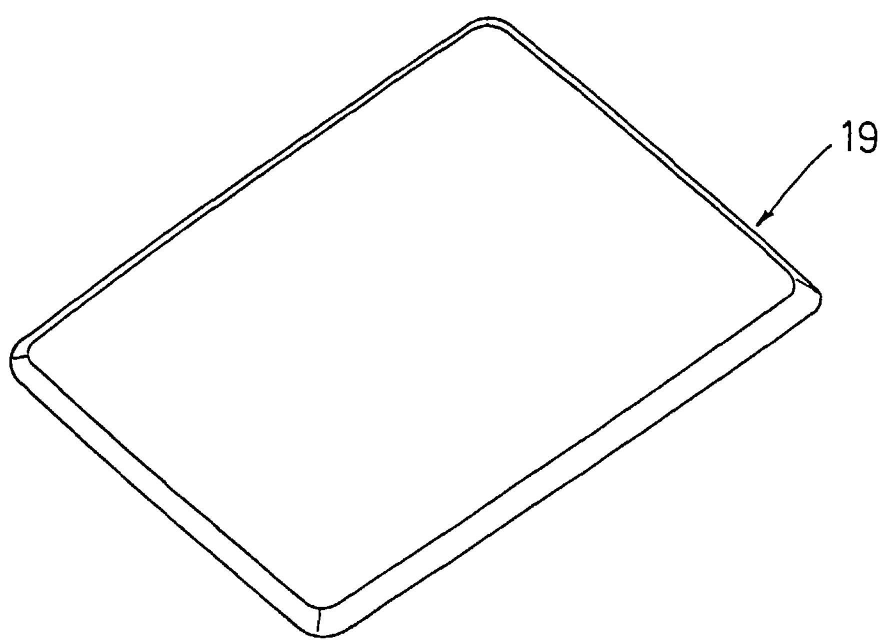

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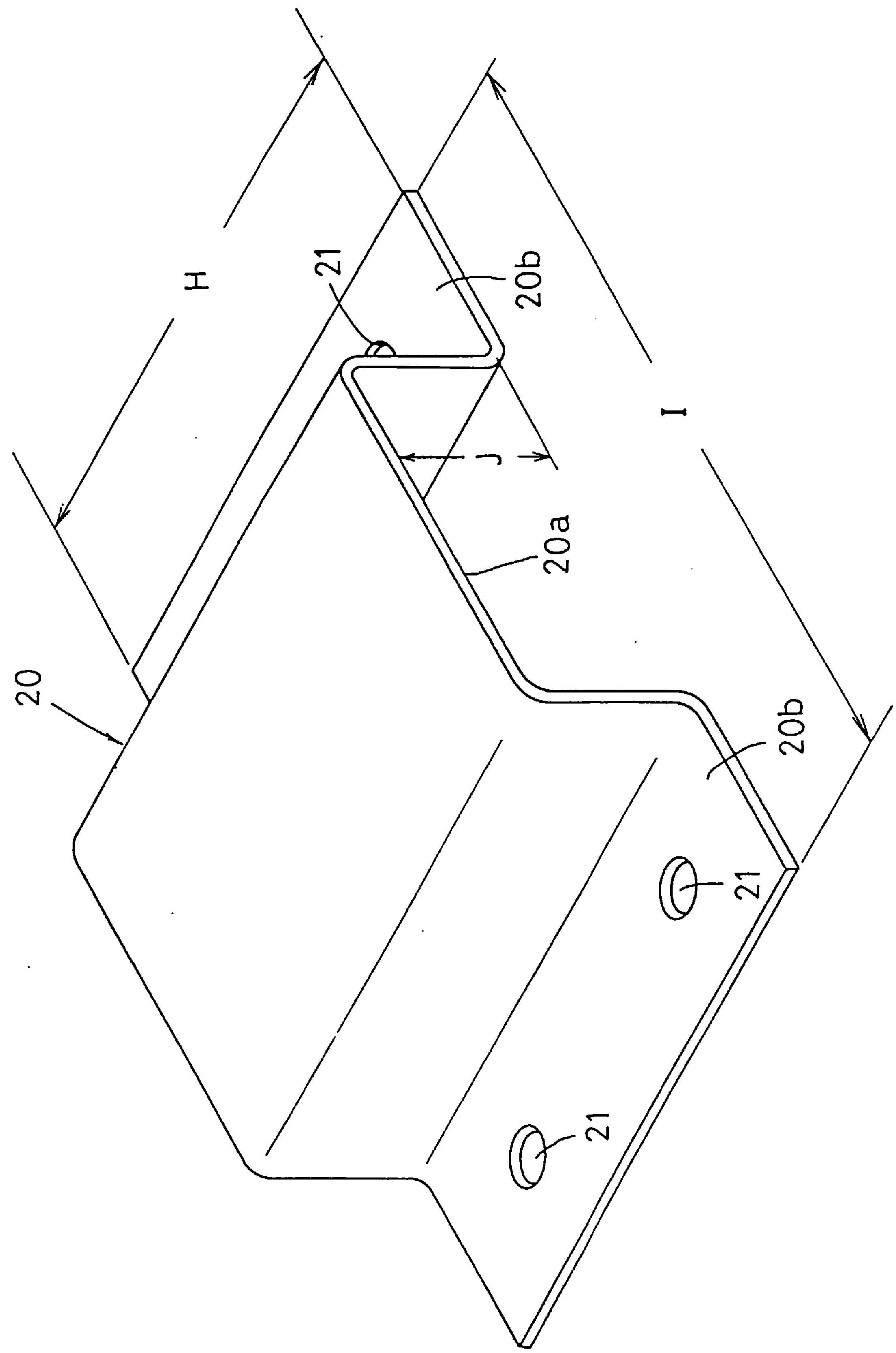

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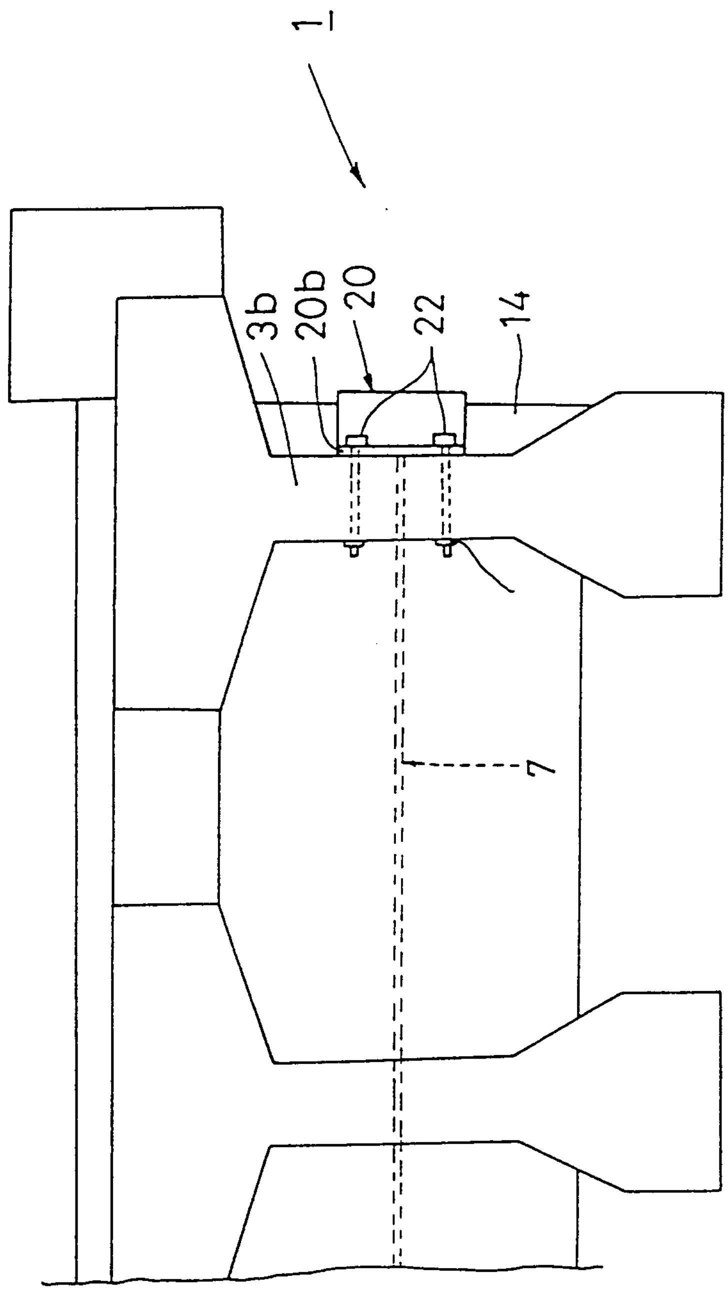

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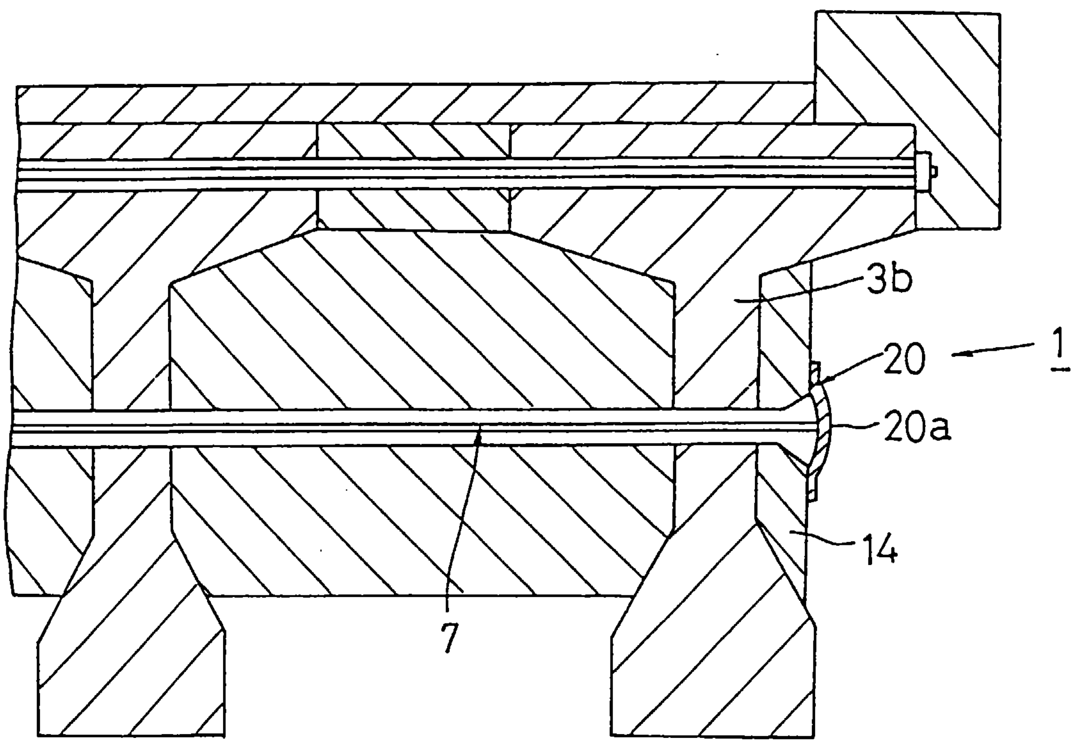

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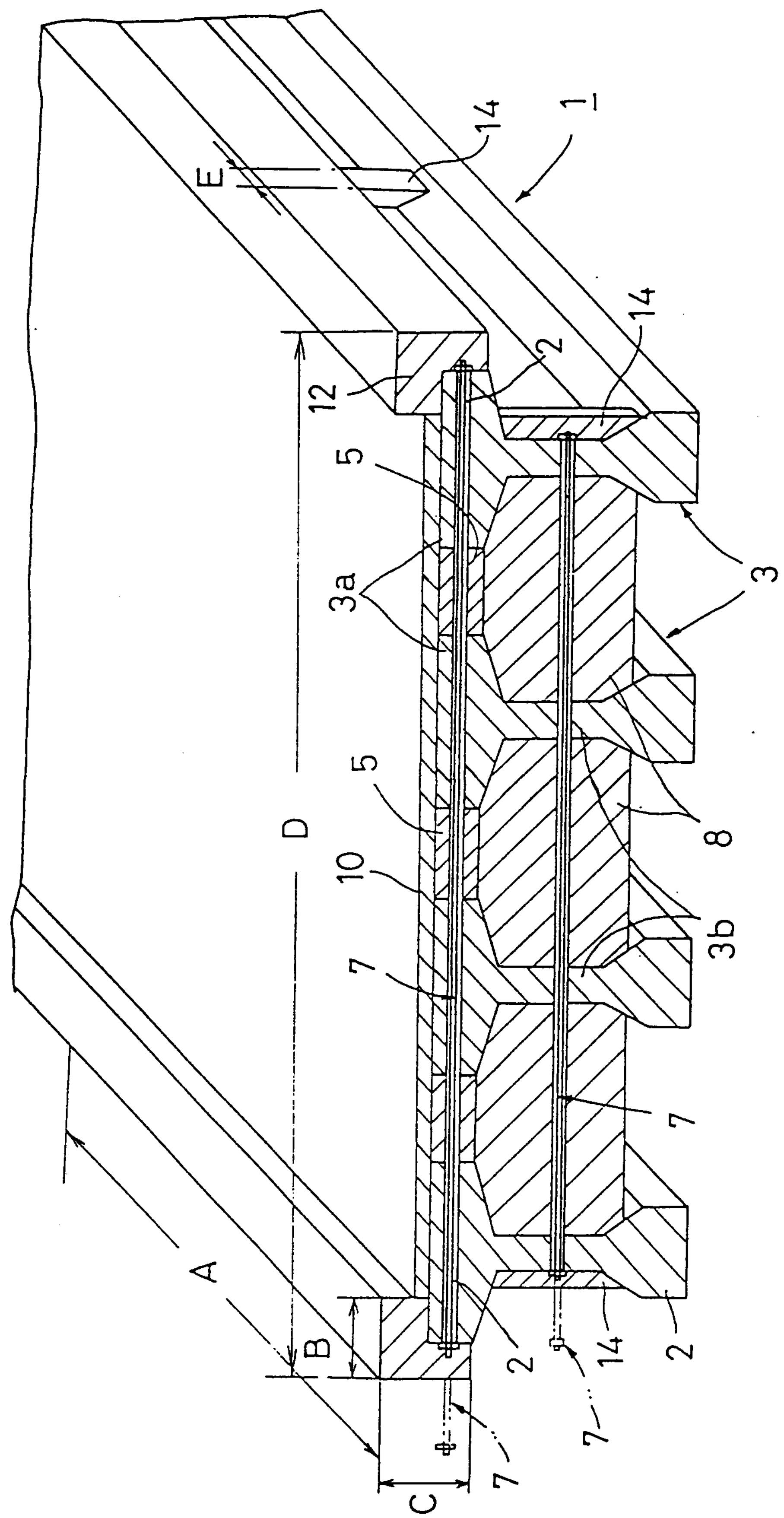

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00599

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 E01D21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 E01D21/00

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

Jitsuyo Shinan Koho	1930 - 1996
Kokai Jitsuyo Shinan Koho	1972 - 1995
Toroku Jitsuyo Shinan Koho	1995 - 1996

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 60-238504, A (Nikkai Giken K.K.), November 27, 1985 (27. 11. 85)	1, 2, 12
A	JP, 4-80161, B (Nippon Kohgen Concrete K.K.), December 17, 1992 (17. 12. 92)	1, 2, 12

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
May 15, 1997 (15. 05. 97)	May 27, 1997 (27. 05. 97)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)