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(54) REINFORCING BAR FOR FRP CONCRETE

(57) A reinforcing bar for FRP concrete having one or more bent portions in which the cross section thereof is shaped substantially into a rectangular in such a manner that the relationship between the thickness t and width w thereof is expressed by t/w<1.

FIG. 1A
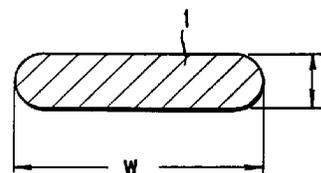
EP 0 774 552 A1

Description

TECHNICAL FIELD

5   The present invention relates to a FRP (Fiber Reinforced Plastic) reinforcement for a concrete. More specifically, the present invention relates to a FRP reinforcement for a concrete such as a stirrup reinforcement for a concrete, a hoop reinforcement for a concrete or the like, in which a bending work is carried out in accordance with a sectional shape of a concrete structure.

10   BACKGROUND ART

As a reinforcement for a concrete, such as a conventional stirrup reinforcement, hoop reinforcement or the like, which is used by bending, a steel reinforcement has been generally used. However, in a case where the sea sands in which salt component and so forth still remains comes to be mixed with a concrete, or in a case where a crack or so
15   forth can be caused in the concrete construction under a severe salt component environment, there arises a problem of corrosion of the above-mentioned reinforcement for the concrete, which occurs by an exposing of the concrete to the salt.
Thus, in the recent years, corrosion resistive FRP rods have been used as the substitute for the steel reinforcement.
As the reinforcement, such as a conventional FRP stirrup, hoop or the like, which is bent is described in for exam-
20   ple, Japanese Unexamined Patent Publication (Kokai) No. Hei 6-136882, the reinforcement is produced by the steps of

(1) inserting a matrix resin impregnated carbon fiber into a flexisible tube;
(2) bending the obtained tube with the matrix resin;
(3) after curing the matrix resin; and
25   (4) removing the flexisible tube to obtain an article.

However, when the curvature of the above-mentioned conventional reinforcement for the concrete is large, it is difficult to increase the strength of the reinforcement around the bending worked portion. Namely,

30   (1) To increase the strength thereof it is necessary to increase the sectional area thereof. Then, the difference between the inside length of the bending worked portion and the outside length thereof becomes large. Thus, a reinforcing fiber bundle of a portion around the inside bending worked portion is subjected to a strong compression force so that the inside bending worked portion has a wrinkle, in the result, the reinforcing fiber orientation is disarranged and the strength of the bending worked portion is remarkably lowered.
35   (2) Further, the disarrangement is advanced to the straight portion of the reinforcement for the concrete, with the result that even the tensile strength of the straight portion thereof is lowered.
(3) Furthermore, when it is subjected to a bending work, a bending worked portion is crushed and it is impossible to maintain such circular sectional shape therein that the straight portion of the reinforcement has. Thus, the sectional shape is warped and the diameter of the entire reinforcement becomes ununiform. This leads to a stress con-
40   centration which results in a cause of lowering the strength of the reinforcement.

As explained above, the conventional FRP reinforcement for the concrete has been produced as a substitute for a conventional steel rod. Therefore, the sectional shape of the former is circular. As a result, when particularly, the bending radius is made small, the strength of the reinforcement is remarkably lowered.
45   Therefore, taking the above-mentioned problems into consideration, it is an object of the present invention to provide a FRP reinforcement for a concrete in which even when the sectional area of the reinforcement is large and the bending radius thereof is small, namely, the curvature thereof is large, a sufficient strength of the bending worked portion thereof can be obtained, and also a strength of the straight portion which continues to the bending worked portion can be sufficiently obtained.

50   DISCLOSURE OF THE INVENTION

In order to accomplish the above-mentioned object of the present invention, according to an aspect of the present invention, there is provided a FRP reinforcement for a concrete having one or more bending worked portions charac-
55   terized in that a shape of the section of the reinforcement is substantially rectangular so that the relationship between the thickness t and the width w satisfies $t/w < 1$.
According to the above-mentioned constitution, a section of a FRP reinforcement for a concrete is substantially rectangular. Therefore, the thickness of the reinforcement can be decreased without changing the sectional area thereof. Thus, a difference between the outside surface length and the inside surface length of the bending worked portion of

the reinforcement is decreased, so that a reinforcing fiber bundle passing through around the inside of the bending worked portion is subjected to only a small compression force. In the result, the disarrangement of the fiber is not generated, so that the strength decrease of the bending worked portion is small.

In the above-mentioned constitution, it is preferable that the relationship between the bending radius R of the inside surface of the bending worked portion and the thickness t satisfies R/t ≧ 2.8.

Further, in the above constitution, it is also preferable that when bending directions of adjoining bending worked portions are the same, the length L of the straight portion between the adjoining bending worked portions satisfies

$$L \geqq 3.5 \times R \times \theta + 3.5 \times R' \times \theta'$$

in which the bending radiuses and bending angles of adjoining bending worked portions are respectively R, θ and R', θ'.

Further, the substantial rectangle may have outwardly curved short sides or an oval shape.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given hereinbelow and from accompanying drawings of the preferred embodiments of the invention, which, however, should not be taken to be limitative to the invention, but are for explanation and understanding only.

In the drawings:

Figs. 1A and 1B show one embodiment of a FRP reinforcement for a concrete according to the present invention, in which Fig. 1A is a sectional view, and Fig. 1B is a side view;

Figs. 2A to 2C show a change of a state and the orientation angle on a bending action for a reinforcing fiber in the bending worked portion of the above-mentioned embodiment, in which Fig. 2A is a diagram illustrating the state before bending work of the reinforcement, Fig. 2B is a diagram illustrating a state where a wrinkle is made by bending work, and Fig. 2C is a diagram illustrating calculation of the orientation angle;

Fig. 3 is a diagram illustrating the tensile strength to the orientation angle in the above-mentioned embodiment of the present invention;

Fig. 4 is a side view illustrating a FRP reinforcement for a concrete in which bending directions of adjoining portions are different from each other, as another embodiment of the present invention;

Fig.s 5A and 5B show a first experimental example of the present invention, in which Fig. 5A is a side view, and Fig. 5B is a sectional view taken along line C-C of Fig. 5A;

Fig. 6 is a side view of a second experimental example of the present invention; and

Fig. 7 is a sectional view of a third experimental example of the present invention.

BEST MODE FOR IMPLEMENTING THE INVENTION

A FRP reinforcement for a concrete according to a preferred embodiment of the present invention will be described below with reference to the accompanying drawings.

As shown in Fig. 1A, a FPR reinforcement for a concrete 1 has a substantially rectangular section with a thickness of t and a width of w. The opposite short sides of the rectangular section are curved outside. When the FPR reinforcement for the concrete 1 is subjected to a bending work so as to have the inside surface bending radius R and the inside surface bending angle θ, as shown in Fig. 1B,

(1) the compression force acts on the inner side portion from the center line 2 across the bending worked portion A and the inner side portion is contracted by (t/2) × θ. However, since a reinforcing fiber 3 can not be contracted and is buckled to have wrinkle. This leads to disarrangement of the orientation of the fiber 3.

(2) This disarrangement of the orientation of the fiber 3 is advanced to a straight portion of the FPR reinforcement. As a result, if the advanced distance X within the straight portion is expressed by using the bending radius R and the bending angle θ, it could be found that X = 3.5 × R × θ by various experiments.

If the length of the fiber 3 in the inner side from the center line 2 shown in Fig. 1B, is defined as LBB' as shown in Fig. 2A, the length LBB' is changed to LAA' due to the formation of wrinkle by the bending work, as shown in Fig. 2B. Therefore, the orientation angle α of the fiber 3 of this portion will be given by the following expressions (refer to Fig. 2C)

$$\cos\alpha = LAA'/LBB'$$

(3) The fiber orientation angle α due to wrinkle is given by the following expressions.

$$\cos\alpha = (R \times \theta + 2 \times X)/\{(R + t/2) \times \theta + 2 \times X\} \tag{1}$$
$$= (R \times \theta + 2 \times 3.5 \times R \times \theta)/\{(R + t/2) \times \theta + 2 \times 3.5 \times R \times \theta\}$$
$$= 8 \times R/(8 \times R + t/2)$$

(4) Fig. 3 is a diagram illustrating the relationship between the fiber orientation angle derived from the disarrangement of the fiber and the tensile strength (load)in a rod-shaped FRP reinforcement for a concrete having a diameter of 10 mm. As shown in Fig. 3, it can be found that when the fiber orientation angle α is larger than substantially 12 degrees the tensile strength is remarkably lowered.

(5) According to the above expression (1), if the condition $\alpha \leqq 12$ degrees is satisfied, $\cos 12° \leqq 8 \times R/(8 \times R + (t/2))$. Then, $R/t \geqq 2.8$. Therefore, if $R/t \geqq 2.8$, that is the width w is broad and the thickness t is sufficiently thin in the bending radial direction, strength decrease due to the disarrangement of the orientation of the fiber 3 is hardly exhibited.

In this connection, even if the reinforcement 1 has any shape of section, when the bending radius is large, the condition $R/t \geqq 2.8$ is satisfied. Then, in the present invention, to cause a bending worked portion to have a sufficient strength even in a bending radius R where when a conventional reinforcement has a circular section the strength thereof is lowered, the section of the reinforcement is caused to be a substantial rectangle having a condition of $t/w < 1$.

Further, the FRP reinforcement for the concrete of the present invention is not different from a conventional FRP reinforcement for a concrete having a circular section in that the former is effective under the following condition.

$$0.1 \times R^2 < S \tag{2}$$

in which the sectional area is S. This reasons are described below.

Namely, in other words, if only the relation $R/t \geqq 2.8$ is satisfied, it is suggested that the strength of the bending worked portions is not lowered by the disarrangement of the fiber orientation even if the section of the reinforcement has any shape. Namely, if the conventional reinforcement having a circular section maintains a relation:

$$S = \pi(t/2)^2 \leqq \pi (R/2/2.8)^2 = 0.1 \times R^2 \tag{3}$$

The decrease of the strength of the bending worked portion of the reinforcement could not be exhibited.

However, the FRP reinforcement for the concrete of the present invention has such a section that the relation $R/t \geqq 2.8$ is satisfied in a condition $t/w < 1$, that is it has substantially rectangular section. Thus, a sufficient strength can be obtained in the bending worked portion of the reinforcement of the present invention.

An oval shaped section may of course be used as the shape of the section of the reinforcement other than the rectangular shaped section having outwardly curved opposite short sides.

(6) Further, since the adjacent bending worked portions A and B are spaced by $3.5R\theta + 3.5R'\theta'$ or more as shown in Fig. 1B, the disarrangement of the fiber orientation in one of the bending worked portions does not affect on the fiber orientation in the other of the bending worked portions. The reasons will be described below.

The above-described expressions (1) and (2) are satisfied when the bending worked portions are respectively independent from each other. When the reinforcement has two or more bending worked portions, such conditions are required that one bending worked portion does not affect other bending worked portions.

Then, a case where a first bending worked portion A having a bending radius of R and a bending angle of θ is adjacent to a second bending worked portion B having a bending radius of R' and a bending angle of θ', as shown in Fig. 1B, is considered.

The length of a straight portion which a first bending worked portion A affects is 3.5θ. A straight portion which is affected by a second bending worked portion should not exist within this range. Therefore, the length L between the bending worked portions A and B should be satisfied as follows.

$$L > 3.5R\theta + 3.5R'\theta' \tag{4}$$

However, when the bending directions of the adjoining bending worked portions A and B are different from each other, as shown in Fig. 4, a fiber which receives a compression force at the first bending worked portion A receives a tensile force at the second bending worked portion B so that both forces are offset to each other. Thus, the straight portion does not require above-discussed distance.

(7) Furthermore, since the FRP reinforcement for the concrete according to the present invention has the substantially rectangular section, the bending worked portion is not crushed, and a stress concentration due to ununiform diameter does not occur, whereby the decrease of the strength of the reinforcement is not exhibited.

As explained above, in the FRP reinforcement for a concrete according to the present invention, a sufficient strength can be obtained in both the bending worked portions and the straight portion.

Next, experimental examples of the present invention will now be described.

(First Experimental Example)

Fig.s 5A and 5B show a first experimental example of the present invention, in which a reinforcement 4 composed of an epoxi resin-impregnated carbon fiber is oriented in one direction (longitudinal direction). The reinforcement 4 has a shape of the section having a substantially rectangular shape in which the width is w and the thickness (height) is t, while being provided with a number of projected portions 5 with the same intervals.

By molding and curing the reinforcement 4 so as to have the thickness t = 3mm, width w = 12.8mm, the radius R = 15mm, and the distance L of the straight portion between the bending worked portions = 200 mm, a hoop shaped FRP reinforcement for a concrete is produced.

Since the distance L of the straight portion between the bending worked portions of the reinforcement 4 satisfies

$$L = 200 > 3.5 \times R \times \theta + 3.5 \times R' \times \theta' = 165,$$

and the relationship between the bending radius R and the thickness t satisfies

$$R/t = 5 > 2.8,$$

then following condition satisfies.

$$\alpha = 9.0° < 12°$$

Consequently, a sufficiently small fiber orientation angle α, a sufficient strength of the bending worked portion and a sufficient tensile strength of the straight portion of the reinforcement 4 could be obtained.

Further, since in the present invention, the bending worked portion is not crushed, (1) the stress concentration due to ununiformness of the thickness t does not occur, (2) an area contacting to a main (straight) reinforcement at the bending worked portion is broad and a thickness thereof is uniform. In the result, the stress which is applied to the bending worked portion from the main reinforcement is small. These are causes that make the strength of the bending worked portion large.

Further, this reinforcement of the present invention has an improved adhesion force to the concrete. The adhesion force to the concrete is preferably provided by unevenness in projected portions of the surface of the concrete. Accordingly, since the surface area to the section area is larger in this example than in a conventional circular section case, a large adhesion strength against the same tensile strength can be obtained.

(Second Experimental Example)

When the thickness of the reinforcement for the concrete must be increased, the problem can be resolved by piling a plurality of them.

Fig. 6 shows this experimental example in which another reinforcement 4a which is one size larger than the reinforcement 4 discussed in the first experimental example is piled on the reinforcement 4 in the thickness direction thereof so that the respective projected and recessed portions are fixed to each other.

Thus, by piling both reinforcements 4 and 4a the strength of this reinforcement is increased. However, since the bending work is carried out every reinforcement, the disarrangement of the fiber orientation at the bending worked portions and the unevenness of the shape of the section do not occur. As a result, the strength of the reinforcement can be increased without increasing the width thereof. Further the number of the reinforcements to be piled are not limited to two, and any number of reinforcement may be piled.

(Third Experimental Example)

In the above-mentioned first and second experimental examples, reinforcements composed of only FRP are described. However, taking the moldability, bending workability, high impact properties or the like into consideration, a FRP core material 6 on the surface of which a coating layer 7 composed of a thermoplastic resin is applied may be used, as shown in Fig. 7. The projected portion 5 shown in Fig. 7 is composed of the thermoplastic resin. Further, an example having no projected portion 5 may be used.

It should be considered that the above-mentioned thickness t and width w correspond to the thickness t_1 and width w_1 of the core material 6, and that the respective relations are calculated by taking the bending radius R as (R + d) or (R + d') including the thickness d of the coating layer 7 or the thickness d' of the projected portion 5 into consideration.

It is not necessary that the coating layer 7 is composed of a thermoplastic resin shown in Fig. 7. For example, a

coating layer 7 which is formed by spirally winding a tape on the FRP core material 6 or another coating layer 7 which is formed by sandwiching the FRP core material 6 by two sheets of films may be used.

As materials which construct the reinforcement for the concrete, particularly as the reinforced fiber for FRP, inorganic fiber such as a carbon fiber, glass fiber or an organic fiber such as aramid fiber is used. Further, as a matrix resin a thermosetting resin such as an epoxi resin, unsaturated polyester, phenolic resin is used.

As explained above, even if the sectional area is broad and the curvature is large, the FRP reinforcement for the concrete of the present invention can have a sufficient bending strength. Also, the strength of the straight portion continuing to this bending portion can have a sufficient strength.

Although the present invention has been illustrated and described with respect to exemplary embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without departing from the gist and scope of the present invention. Therefore, the present invention should not be understood as limited to the specific embodiments set out above but to include all possible embodiments which can be embodied within a scope encompassed and equivalents thereof with respect to the features set out in the appended claims.

Claims

1. A FRP reinforcement for a concrete having one or more bending worked portions characterized in that a sectional area of the reinforcement is substantially rectangular so that the relationship between the thickness t and the width w satisfies t/w < 1.

2. A FRP reinforcement for a concrete according to claim 1, wherein the relationship between the bending radius R of the inner side of the bending worked portion and the thickness t satisfies $R/t \cong 2.8$.

3. A FRP reinforcement for a concrete according to claim 1 or 2, wherein when bending directions of adjoining bending worked portions are the same, the length L of the straight portion between said adjoining bending worked portions satisfies

$$L \cong 3.5 \times R \times \theta + 3.5 \times R' \times \theta'$$

in which the bending radius the inner side of the bending worked portion and the bending angle are respectively R, θ and R', θ'.

4. A FRP reinforcement for a concrete according to any one of claims 1 to 3, wherein said substantial rectangle has outwardly curved short sides.

5. A FRP reinforcement for a concrete according to any one of claims 1 to 3, wherein said substantial rectangle is an oval shape.

6. A FRP reinforcement for a concrete according to claim 1, wherein a number of equally-spaced projected portions 5 are provided at both the side surfaces.

7. A FRP reinforcement for a concrete according to claim 1 or 6, wherein another reinforcement which is one size larger than said reinforcement is piled thereon in the thickness direction of said reinforcement.

8. A FRP reinforcement for a concrete according to claim 1 or 6, wherein using a FRP as a core material, a coating layer composed of thermoplastic resin is provided on the surface of the core material.

9. A FRP reinforcement for a concrete according to claim 1 or 6, wherein using a FRP as a core material, a coating layer is formed by winding a tape spirally on the surface of the core material.

10. A FRP reinforcement for a concrete according to claim 1 or 6, wherein using a FRP as a core material, a coating layer is formed by sandwiching the core material by said two sheets of films.
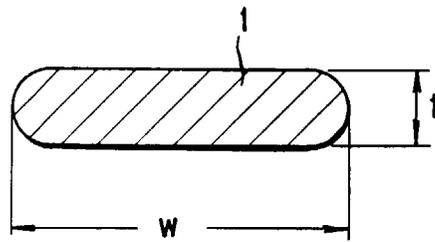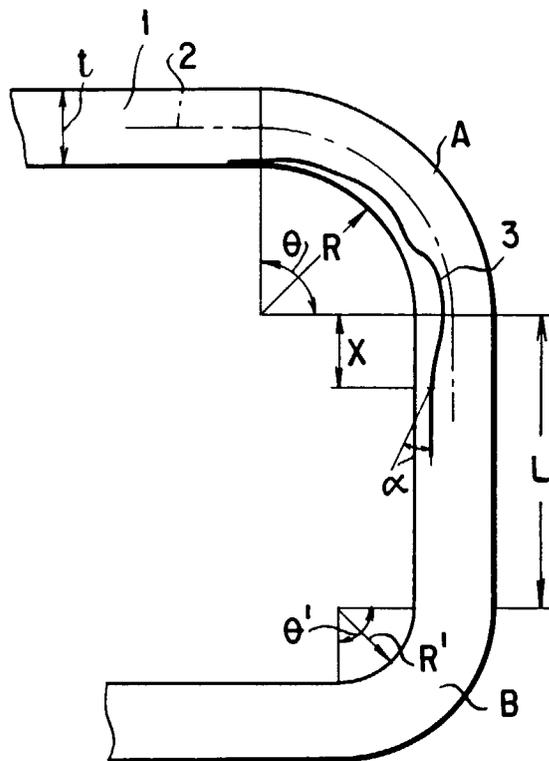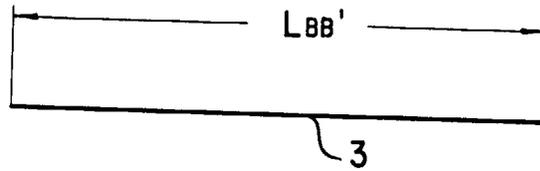
FIG. 1A

FIG. 1B

FIG. 2A

$$L_{BB'}$$

3

FIG. 2B

$$L_{AA'}$$

3

α

FIG. 2C

$$L_{BB'}$$

α

$$L_{AA'}$$
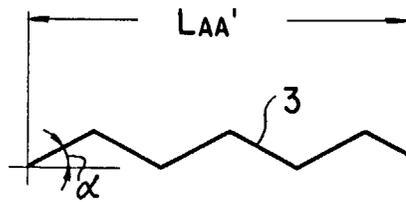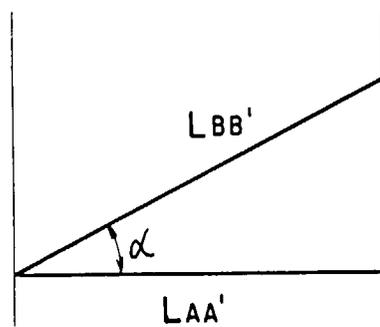
FIG. 3
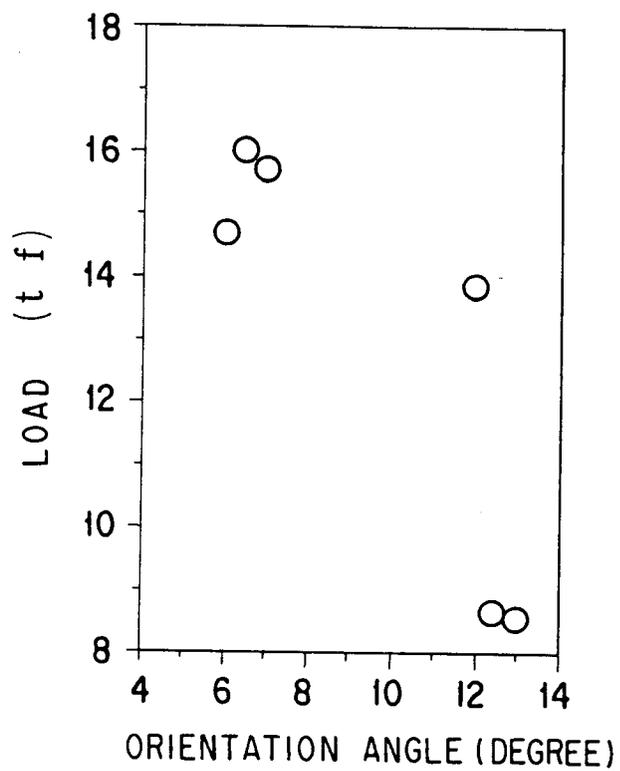
FIG. 4
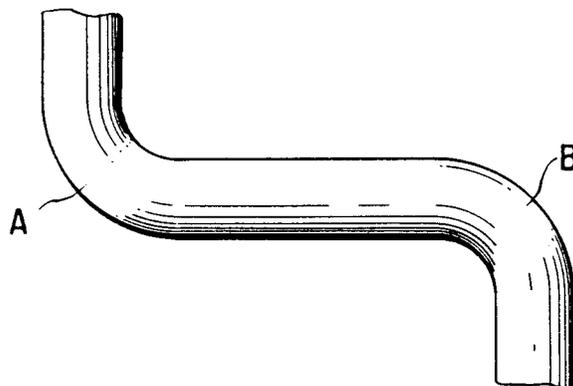
FIG. 5A
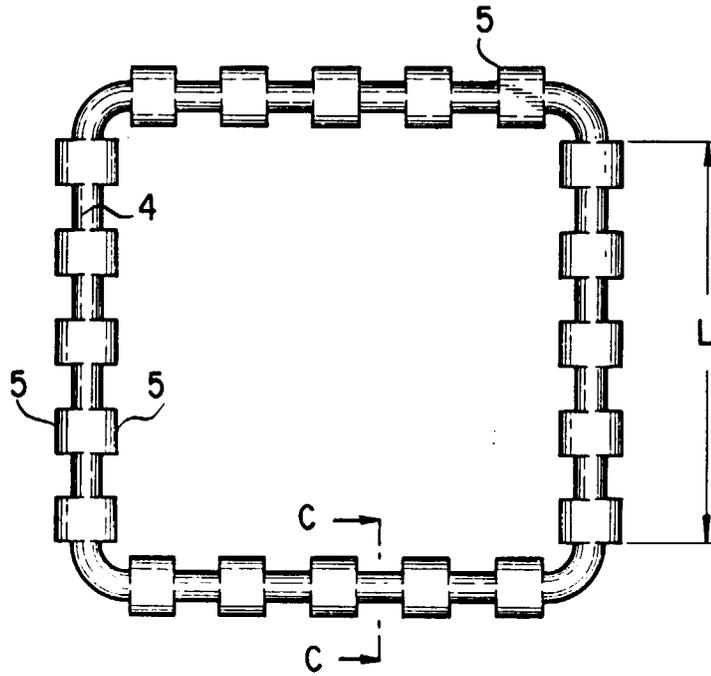
FIG. 5B

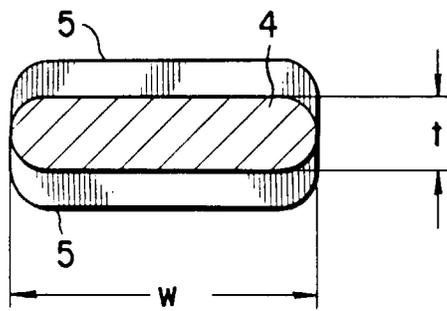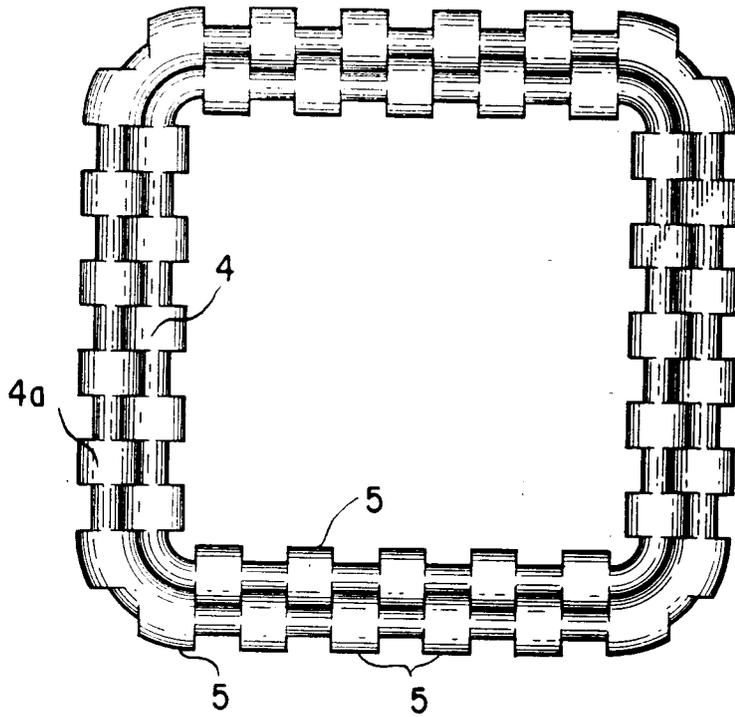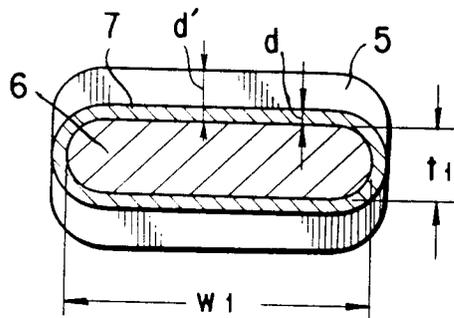# FIG. 6

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP95/01528

A.	CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 E04C5/07

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 E04C5/07

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

Jitsuyo Shinan Koho	1926 – 1995
Kokai Jitsuyo Shinan Koho	1971 – 1995
Toroku Jitsuyo Shinan Koho	1994 – 1995

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.
X	JP, 1-121450, A (Shimizu Construction Co., Ltd. and another), May 15, 1989 (15. 05. 89), Figs. 1, 2, 4 (Family: none)	1, 5, 8
Y	JP, 1-121450, A (Shimizu Construction Co., Ltd. and another), May 15, 1989 (15. 05. 89)	2-4, 6-7, 9-10
X	JP, 2-118175, A (Mitsui Construction Co., Ltd.), May 2, 1990 (02. 05. 90), Figs. 1, 3 (Family: none)	1, 5, 8
Y	JP, 2-118175, A (Mitsui Construction Co., Ltd.), May 2, 1990 (02. 05. 90)	2-4, 6-7, 9-10
Y	JP, 63-221035, A (Showa Highpolymer Co., Ltd.), September 14, 1988 (14. 09. 88)(Family: none)	1, 6, 8
Y	JP, 53-159115, U (Toray Industries, Inc.), December 13, 1978 (13. 12. 78)(Family: none)	8 - 10

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier document but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
September 14, 1995 (14. 09. 95)	October 3, 1995 (03. 10. 95)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP95/01528

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 61-35231, A (Mitsui Construction Co., Ltd.), February 19, 1986 (19. 02. 86) & US, 4770832, A & EP, 170499, A2	9

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