

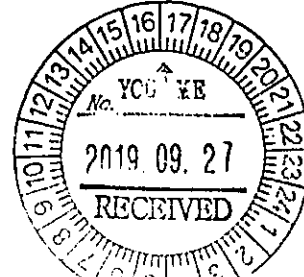
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September 24, 2019

YOU ME Patent & Law Firm
Seolim Building, 115 Teheran-ro,
Gangnam-gu, Seoul
06134, Korea



Re: **U.S. Patent No. US 10,414,691 B2**
U.S. Application Serial No. 15/510,305
ARCHED STEEL FIBERS FOR REINFORCING CEMENT-BASED MATERIAL
Your Ref. OPP20170356US
Our Ref. 272-1-LPP20170356US

Dear Sirs:

Please find enclosed the Official Letters Patent issued by the USPTO for the above-referenced patent. The official date of registration is September 17, 2019.

Please do not hesitate to contact us if you have any question regarding above.

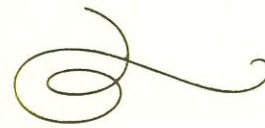
Kindest regards,

A handwritten signature in cursive script, appearing to read "Jongwon Kim".

Jongwon Kim

JWK
Enclosures

United
States
of
America



To Promote the Progress

of Science and Useful Arts

The Director

of the United States Patent and Trademark Office has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this United States

Patent

grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, of the right to exclude others from using, offering for sale or selling throughout the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b). See the Maintenance Fee Notice on the inside of the cover.

Andres Ibarra

DIRECTOR OF THE UNITED STATES PATENT AND TRADEMARK OFFICE



Maintenance Fee Notice

If the application for this patent was filed on or after December 12, 1980, maintenance fees are due three years and six months, seven years and six months, and eleven years and six months after the date of this grant, or within a grace period of six months thereafter upon payment of a surcharge as provided by law. The amount, number and timing of the maintenance fees required may be changed by law or regulation. Unless payment of the applicable maintenance fee is received in the United States Patent and Trademark Office on or before the date the fee is due or within a grace period of six months thereafter, the patent will expire as of the end of such grace period.

Patent Term Notice

If the application for this patent was filed on or after June 8, 1995, the term of this patent begins on the date on which this patent issues and ends twenty years from the filing date of the application or, if the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121, 365(c), or 386(c), twenty years from the filing date of the earliest such application (“the twenty-year term”), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b), and any extension as provided by 35 U.S.C. 154(b) or 156 or any disclaimer under 35 U.S.C. 253.

If this application was filed prior to June 8, 1995, the term of this patent begins on the date on which this patent issues and ends on the later of seventeen years from the date of the grant of this patent or the twenty-year term set forth above for patents resulting from applications filed on or after June 8, 1995, subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b) and any extension as provided by 35 U.S.C. 156 or any disclaimer under 35 U.S.C. 253.



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(12) **United States Patent**
Won et al.

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(45) **Date of Patent:** **Sep. 17, 2019**

(54) **ARCHED STEEL FIBERS FOR REINFORCING CEMENT-BASED MATERIAL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 266 days.

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PCT Pub. Date: **Mar. 31, 2016**

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B21D 13/10 (2006.01)
E04C 2/30 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **C04B 14/48** (2013.01); **C04B 14/38** (2013.01); **E04C 5/012** (2013.01); **Y10T 428/1241** (2015.01)

(58) **Field of Classification Search**
CPC . **C04B 14/38**; **C04B 14/48**; **E04C 5/01**; **E04C 5/012**; **E04C 5/073**; **Y10T 428/12354**; **Y10T 428/1241**
See application file for complete search history.

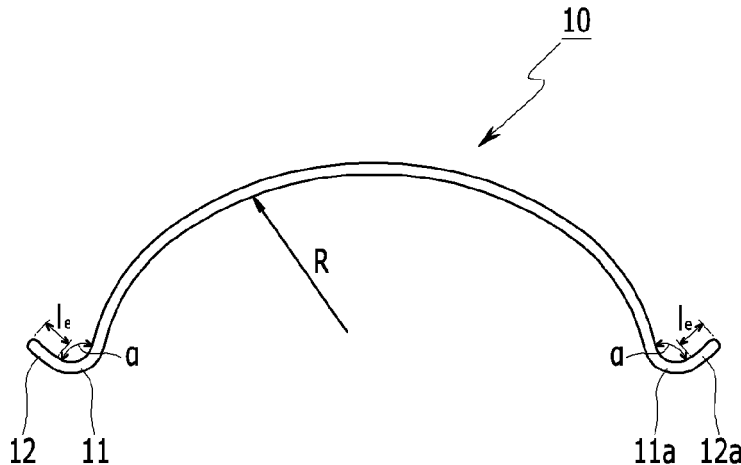
(56) **References Cited**
U.S. PATENT DOCUMENTS
2,705,897 A * 4/1955 Kentish B25B 13/463
81/119
4,420,153 A * 12/1983 Winkler B65H 3/063
271/202
(Continued)

FOREIGN PATENT DOCUMENTS
EP 0484531 A1 * 5/1992 E04C 5/012
JP 06-294017 10/1994
(Continued)

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(57) **ABSTRACT**
The present invention discloses an arched steel fiber for reinforcement of a cement-based material, of which a main body is arched in a length direction and opposite ends of the main body are curved such that the steel fiber has a higher pullout resistance strength compared to a conventional steel fiber, thereby improving mechanical performance such as a tensile strength, a flexural strength, an energy absorption capability, and the like of a cement compound. In addition, compared to a conventional art, a mixing amount of steel fiber to performance can be reduced so that an added economic value in terms of consumable cost can be created.

1 Claim, 7 Drawing Sheets



- (51) **Int. Cl.**
C04B 14/48 (2006.01)
C04B 14/38 (2006.01)
E04C 5/01 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,764,488 A * 8/1988 Saito C04B 35/76
428/364
6,060,163 A 5/2000 Naaman
9,045,901 B2 * 6/2015 Lambrechts E04C 5/012
2013/0255540 A1 * 10/2013 Lambrechts E04C 5/012
106/644

FOREIGN PATENT DOCUMENTS

KR 10-2002-0081706 10/2002
KR 20-0361900 9/2004
KR 200361900 9/2004
KR 2004406191 1/2006
KR 10-2011-0050628 5/2011
KR 10-2011-0051914 5/2011
KR 101073393 10/2011
KR 20130129385 11/2013
KR 10-1403659 6/2014
KR 101403659 6/2014

* cited by examiner

FIG. 1

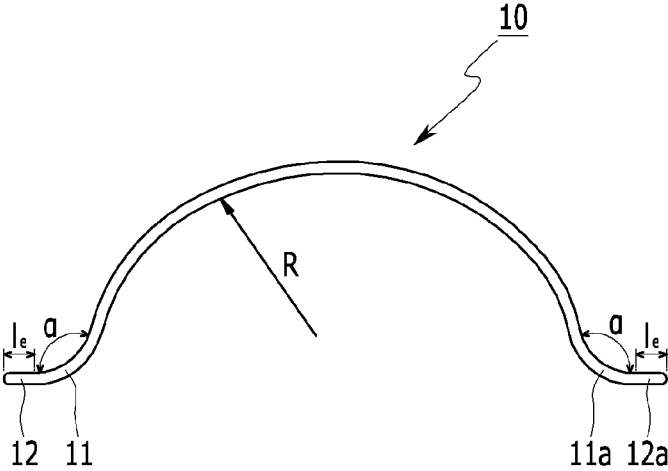


FIG. 2

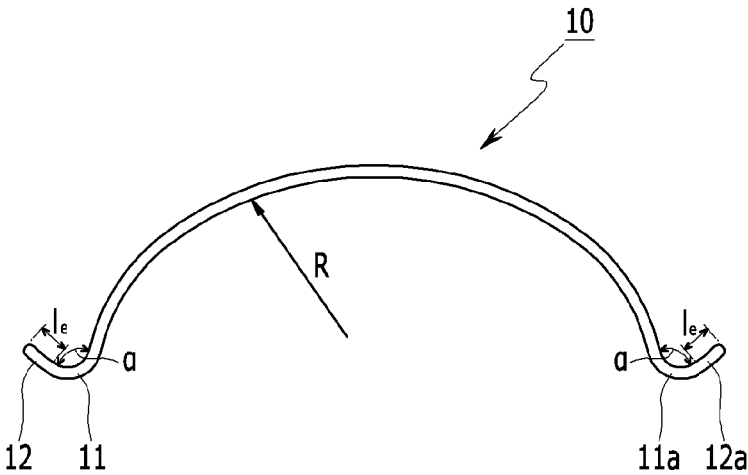


FIG. 3

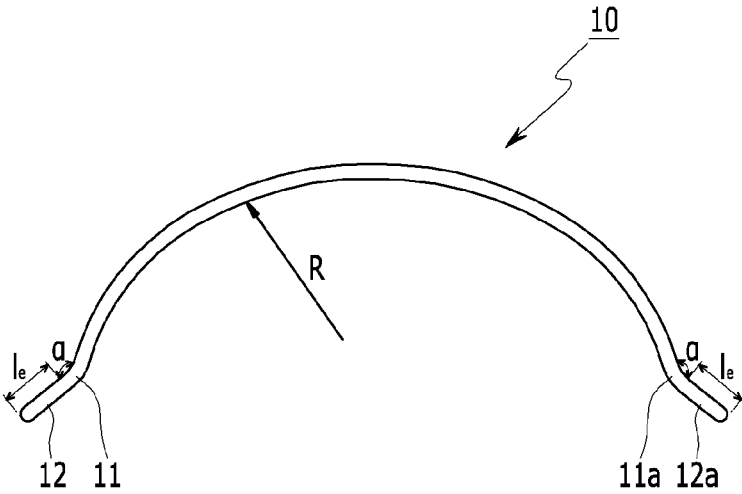


FIG. 4

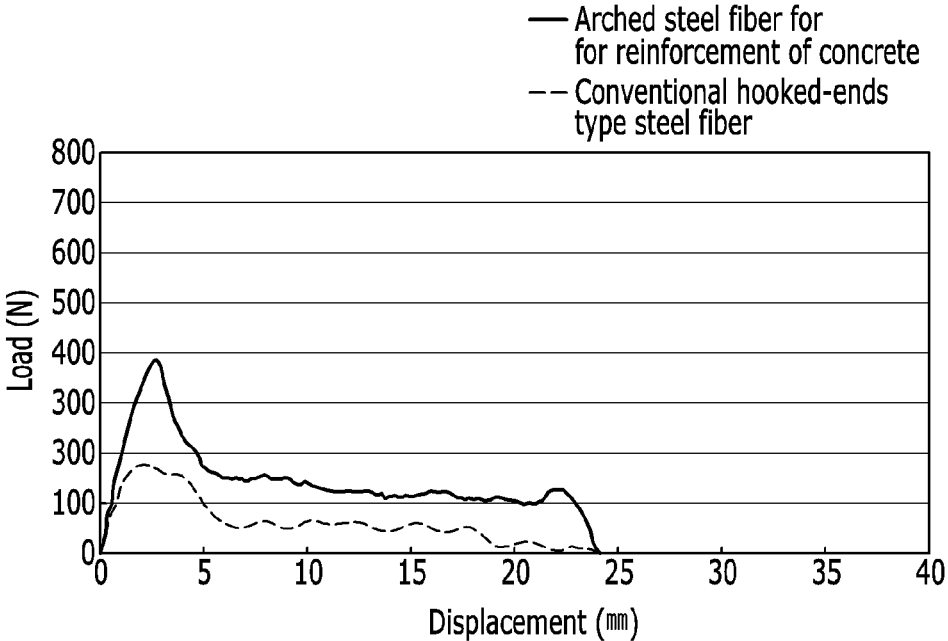


FIG. 5

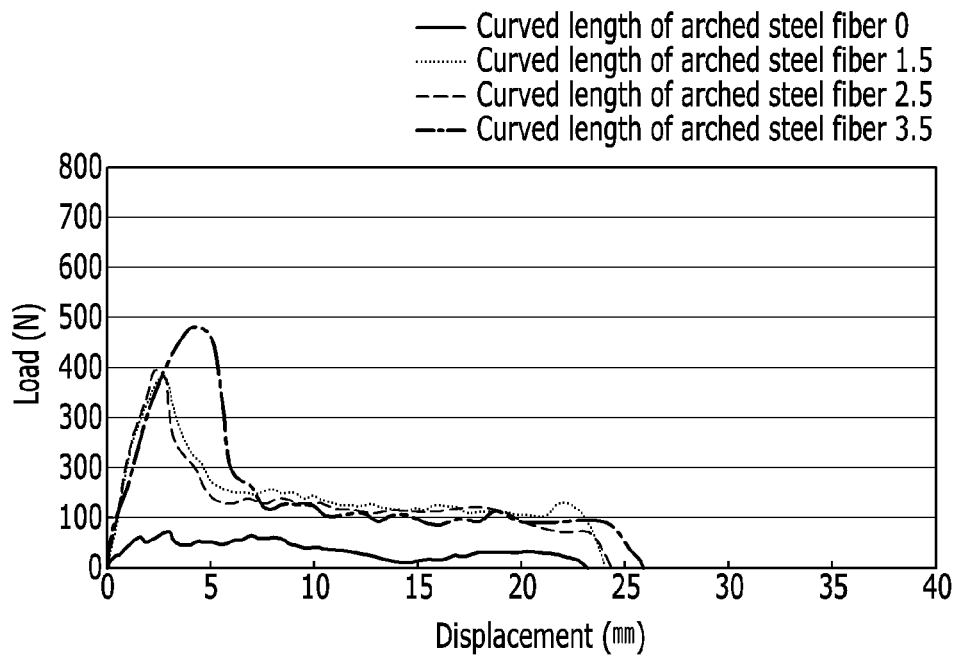


FIG. 6

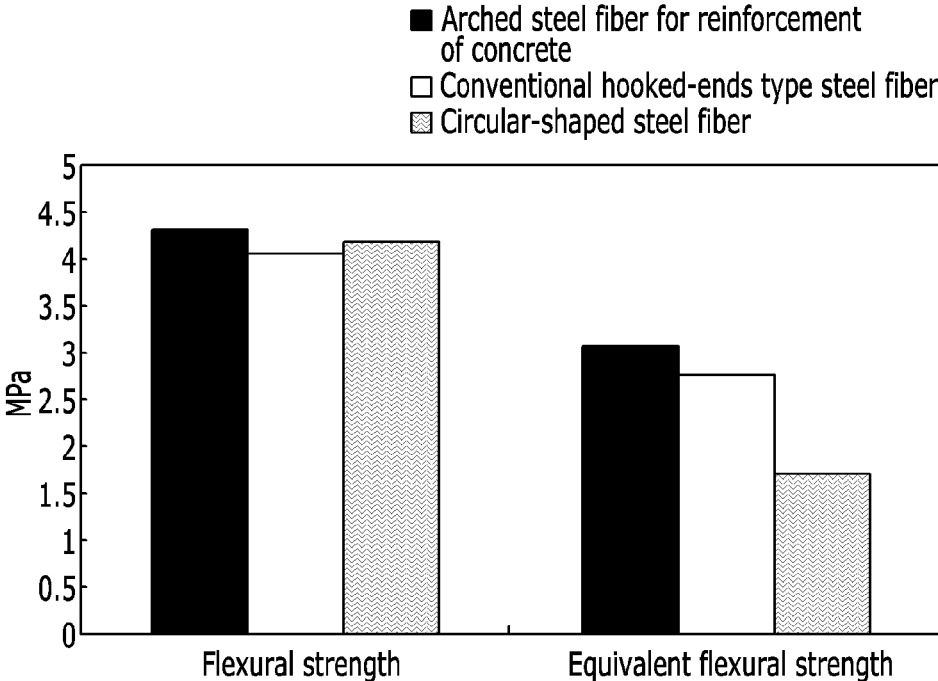
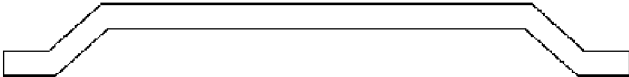


FIG. 7 (Prior Art)



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ARCHED STEEL FIBERS FOR REINFORCING CEMENT-BASED MATERIAL

TECHNICAL FIELD

The present invention relates to arched steel fiber for reinforcement of a cement-based material. More particularly, it relates to arched steel fiber that can improve mechanical characteristics such as crack control, impact resistance, flexural toughness, and the like by increasing adhesion force in mixing with a cement-based composition by forming curved ends at opposite ends of the arched steel fiber.

BACKGROUND ART

In general, concrete has excellent compression strength, durability, and hardness, but has low tensile strength, flexural strength, impact strength, and energy absorption capability, thereby having weak limits under tensile or dynamic loading.

In order to ameliorate such a weakness, a method for reinforcing cement by using a predetermined steel fiber has been widely used, and the size of the steel fiber and a mixing amount of the steel fiber are adjusted depending on the application.

Various types of steel fiber related technologies, such as straight steel fiber having hooked ends and a circular cross-section disclosed in Korean Patent Laid-Open Publication No. 2013-0129385, ring-shaped steel fiber of which opposite ends are disposed apart from each other to improve flexural toughness by reducing a rebound rate when depositing and preventing extraction after depositing, and the like, have been disclosed until now.

As described, a conventional concrete reinforcing steel fiber has been applied to shotcrete, which is a secondary passive reinforcing member, in tunnel excavation, and is commonly applied to a floor slab which requires crack control and has a difficulty in reinforcement using steel bars due to its small cross-section.

Steel fiber applied to the shotcrete has a diameter of 0.5 mm to 0.55 mm and a length of 30 mm to 35 mm, but steel fiber applied to the floor slab usually has a diameter of 0.75 mm to 0.90 mm and a length of 50 mm to 60 mm.

In a case of a conventional hooked steel fiber which is as shown in FIG. 7, opposite ends of a straight main body are generally formed in the shape of a hook by bending the opposite ends at a predetermined angle. This is because, when the steel fiber is pulled out from the concrete due to a tensile force applied thereto after a crack is generated, adhesion performance is deteriorated since there is a significant deterioration of pullout resistance strength in the straight portion, except for the hooked portion. Accordingly, the conventional hooked steel fiber cannot improve mechanical performance.

In order to solve such a problem, various techniques that implement characteristics have been disclosed in Korean Patent No. 1,073,393, Korean Utility Nos. 361,900 and 406,191, and U.S. Pat. No. 6,060,163.

However, the conventional concrete reinforcing steel fiber, specifically, steel fibers that are designed for improvement adhesion performance, require a relatively short length or high tensile strength so as to improve adhesion performance.

In particular, in case of steel fiber having ring-shaped separated ends like the steel fiber disclosed in Korean Patent Laid-Open Publication No. 1,403,659, the ring-shaped sepa-

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rated ends are disposed higher than a center portion and each end is provided with a closely attached portion that protrudes inwardly and downwardly with an inclination. However, circular-shaped opposite ends need a lapped welding treatment, which may cause quality deterioration or productivity deterioration due to a welding failure.

DISCLOSURE

Technical Problem

The present invention has been made in an effort to provide an arched steel fiber for reinforcement of a cement-based material for improvement of mechanical performance between steel fiber and the cement-based material by integrally forming curved ends to opposite ends of the main body.

In addition, the present invention can provide the arched steel fiber for reinforcement of the cement-based material that can create added economic value in terms of consumable cost by reducing a mixing amount of steel fiber to performance.

Technical Solution

An arched steel fiber for reinforcement of a cement-based material according to an exemplary embodiment of the present invention includes an arched main body having a curvature radius and curved and straight ends respectively provided at opposite ends of the main body.

Particularly, the curved ends are bent in a direction that is opposite to a direction that the main body is arched, and the straight ends are continued to the curved ends, respectively.

Advantageous Effects

According to the exemplary embodiment of the present invention, the opposite ends of the arched steel fiber for reinforcement of the cement-based material are bent, respectively, and the main body is arched along a length direction thereof so that the steel fiber can provide much higher pullout resistance strength compared to the conventional steel fiber, and mechanical performance such as tensile strength, flexural strength, energy absorption capability, and the like can be improved.

In particular, unlike the conventional hooked steel fiber of which pullout resistance strength is significantly reduced at straight ends after the hooked portion, the arched steel fiber for reinforcement of the cement-based material can maintain the pullout resistance strength because the entire length of the arched steel fiber resists a pullout load.

In addition, in case of a conventional semi-circular shaped steel fiber, fibers are balled when being mixed into a cement compound, thereby causing a problem in workability, and high friction occurs in a cement matrix when the fiber is pulled out from the cement-based compound, thereby requiring higher tensile strength than a steel wire, which is used in general so as to improve pullout performance.

However, the arched steel fiber for reinforcement of cement-based material according to the exemplary embodiment of the present invention has an appropriate curvature radius so that the fiber can be pulled out from the cement matrix and thus higher level tensile strength is not additionally required, and workability can be improved. Accordingly, the arched steel fiber for reinforcement of cement-based material according to the exemplary embodiment of the present invention can supplement drawbacks of the

conventional hooked, circular-shaped, and semi-circular-shaped steel fiber and highlight merits thereof.

Further, compared to the conventional steel fiber for reinforcement of a cement-based material, the arched steel fiber for reinforcement of cement-based material according to the exemplary embodiment of the present invention can drastically reduce a mixing amount of the steel fiber compared to performance, thereby obtaining technical effects such as creating added economical value in terms of consumable cost.

In addition, the arched steel fiber for reinforcement of cement-based material according to the exemplary embodiment of the present invention can secure the durability for extending the life of the cement composite structure from the elasticity of the main body and improve manufacturing and productivity due to the simple construction of the structure.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows arched steel fiber for reinforcement of a cement-based material according to a first exemplary embodiment of the present invention.

FIG. 2 shows arched steel fiber for reinforcement of a cement-based material according to a second exemplary embodiment of the present invention.

FIG. 3 shows arched steel fiber for reinforcement of a cement-based material according to a third exemplary embodiment of the present invention.

FIG. 4 and FIG. 5 are graphs that show results of a pullout test performed on the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention.

FIG. 6 is a graph that shows a result of a bending test performed on the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention.

FIG. 7 shows steel fiber for reinforcement of a cement-based material according to a conventional art.

MODE FOR INVENTION

Hereinafter, a technical configuration of arched steel fiber for reinforcement of a cement-based material according to an exemplary embodiment of the present invention will be described in detail with reference to the accompanying drawings.

First, as shown in FIG. 1 to FIG. 3, arched steel fiber for reinforcement of a cement-based material according to an exemplary embodiment of the present invention includes an arched main body **10** and predetermined curved ends **11** and **11a** and straight ends **12** and **12a** that are respectively provided at opposite ends of the main body **10**.

The curved ends **11** and **11a** and the straight ends **12** and **12a** are respectively integrally provided at the opposite ends of the main body **10**. That is, the curved portions **11** and **11a** are formed with a predetermined angle α and the straight ends **12** and **12a** are formed with a predetermined length l_e , respectively, at the opposite ends of the main body **10**.

The arched main body **10** provides stronger pullout resistance strength compared to a conventional art, and ultimately, provides a technical effect of improving mechanical performance such as tensile strength, flexural strength, energy absorption capability, and the like of the cement composite.

In particular, the curved ends **11** and **11a** of the arched steel fiber for reinforcement of the cement-based material

according to the exemplary embodiment of the present invention are bent in a direction that is opposite to the arch-shape of the main body **10**.

In this case, the straight portions **12** and **12a** are respectively extended from the curved portions **11** and **11a**.

The arched main body **10** may have a predetermined curvature radius R. For example, the curvature radius R of the main body **10** may have various values between 5 mm and 80 mm. Here, a straight length of the steel fiber may be changed depending on the arch curvature radius R of the main body **10**.

A total length of the steel fiber, that is, the total length of the main body **10**, the curved ends **11** and **11a**, and the straight ends **12** and **12a**, may be set within a range of 10 mm to 90 mm to obtain a tensile strength of 500 MPa to 2800 MPa and a tensile elastic coefficient of 200 GPa or more.

When the curvature radius R of the main body **10** is 5 mm or less, the entire size of the steel fiber is reduced so that it is difficult to expect elasticity from the arched shape, and when curvature radius R of the main body **10** exceeds 80 mm, an elastic synergistic effect of the plurality of steel fibers may be deteriorated due to the total length.

The angle α of the curved ends **11** and **11a** may vary within a range of 30° to 160°.

In addition, the length l_e of the straight ends **12** and **12a** may preferably be set to be within a range of 0.5 mm to 10 mm.

Here, The angle α of the curved ends **11** and **11a** or the length l_e of the straight ends **12** and **12a** has a close relationship with mechanical adhesion performance in concrete when the arched steel fiber is mixed with a corresponding cement-based material.

When the angle α of the curved ends **11** and **11a** is less than 30° or exceeds 160°, or when the length l_e of the straight ends **12** and **12a** is less than 0.5 mm, the mechanical adhesion performance in the corresponding concrete is only somewhat enhanced. Further, when the length l_e of the straight ends **12** and **12a** is set to be longer than 10 mm, unnecessary waste of materials may occur.

Exemplary Embodiment 1

In order to determine adhesion performance of the arched steel fiber for the cement-based material according to the exemplary embodiment of the present invention, a pullout test was performed on the arched steel fiber for the cement-based material according to the exemplary embodiment of the present invention and conventional hook-type steel fiber for the cement-based material.

In order to perform the pullout test, a dog-bone-shaped mortar specimen was divided into two portions according to JCI SF-8, and then a steel fiber was embedded 25 mm into each center of the divided portions.

Compression strength of the mortar was 30 MPa, and steel fibers used in the pullout test each had a tensile strength of 1300 MPa, a diameter of 0.75 mm, and a length of 60 mm.

In manufacturing of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention, a curvature radius R of the arch was set to 35 mm, the angle α of the curved ends **11** and **11a** was set to 90°, and the length l_e of the straight ends **12** and **12a** was set to 1.5 mm.

Results of the pullout test, as shown in the graph of FIG. 4, shows that a maximum pullout load of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention is

improved by 115% compared to the conventional steel fiber for reinforcement and a pullout resistance strength after the maximum pullout load is improved by 125%.

A result of observation of the surface of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention shows that friction marks with a cement matrix remain all over the embedded length of the steel fiber, but in case of the conventional steel fiber for reinforcement, the friction marks

Table 1 shows a mixing ratio of concrete for determination of bending performance, and steel fiber that has the same specification as of the arched steel fiber of Exemplary Embodiment 1 for the pullout test and the hooked-type steel fiber were applied, and in the case of the circular-shaped steel fiber, the tensile strength was 1300 MPa, the diameter was 0.75 mm, and the interior diameter was 30 mm. A mixing amount was 30 kg/m².

TABLE 1

Design standard Compression strength (MPa)	Coarse aggregate Maximum size (mm)	Air amount (%)	Unit material amount (kg/m ³)						High performance AE water reducing agent (standard) (AD)
			S/a (%) Water (W)	W/C (%)	Cement (C)	Fine aggregate (S)	Coarse aggregate (G)		
24	25	5	47.8	47.1	173	367	846	924	5.32

remain only in a hook portion. Accordingly, it can be determined that the entire length of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention resists the pull-out.

Exemplary Embodiment 2

In order to determine adhesion performance according to the length l_e of the straight lines **12** and **12a** of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention, a pullout test was performed with the length l_e of the straight lines **12** and **12a** as a variable.

A pullout test method, an embedment length, and a compression strength of mortar were set to be the same as those of Exemplary Embodiment 1, and steel fibers used in the pullout test were prepared with a tensile strength of 1300 MPa, a diameter of 0.75 mm, and a length of 60 mm. The lengths l_e of the straight ends **12** and **12a** were respectively set to 0, 1.5 mm, 2.5 mm, and 3.5 mm.

As shown in the results of the pullout test, represented by the graph of FIG. 5, maximum pullout loads of the straight ends **12** and **12a** were improved by 437%, 450%, and 575%, respectively, when the lengths l_e of the straight ends **12** and **12a** were set to 1.5 mm, 2.5 mm, and 3.5 mm, respectively, with reference to 0 mm of the length l_e of the straight ends **12** and **12a**, and pullout resistance strengths after the maximum pullout loads were improved by 102%, 110%, and 122%, respectively.

Exemplary Embodiment 3

In order to determine bending performance of concrete reinforced by the arched steel fiber according to the exemplary embodiment of the present invention, bending performance was tested on the arched steel fiber, the conventional hook-type steel fiber, and circular-shaped steel fiber.

A specimen used in the test was manufactured as a 150 mm×150 mm×550 mm specimen having a prismatic shape, and a third-point bending test was performed according to JSCE-SF4.

Compression strength was measured after being aged for 28 days, and a result of the measurement shows that the conventional hook-type steel fiber, the circular-shaped steel fiber, and the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment satisfied the design standard compression strength.

As shown in the graph of FIG. 6, a bending test result shows that flexural strength of concrete reinforced with the conventional hook-type steel fiber was 4.045 MPa, flexural strength of concrete reinforced with the conventional circular-shaped steel fiber was 4.178 MPa, and concrete reinforced with the arched steel fiber of the present invention was 4.302 MPa, and equivalent flexural strengths were respectively 2.751 MPa, 1.709 MPa, and 3.057 MPa, respectively.

That is, compared to the conventional hook-type steel fiber and the conventional circular-shaped steel fiber, flexural strength of the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention was improved by 6.35% and 2.97%, and the equivalent flexural strength was improved by 11.1% and 78.9%.

In the concrete reinforced with the arched steel fiber for reinforcement of the cement-based material according to the exemplary embodiment of the present invention and in the concrete reinforced with the conventional hook-type steel fiber, deflection of the specimen and weight loss did not significantly occur after the first crack. However, in the case of the concrete reinforced with the circular-shaped steel fiber, the specimen was deflected and load loss significantly occurred as the steel fiber rupture occurred after the first crack.

Hereinabove, the arched steel fiber for reinforcement of the cement-based material was described as an exemplary embodiment of the present invention for convenience of description, however, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

The invention claimed is:

1. An arched steel fiber for reinforcement of a cement-based material, comprising an arched main body having a

curvature radius R, curved ends respectively formed integrally at opposite ends of the main body, and a straight end extending from each of the curved ends,

wherein the curved ends are bent in a direction that is opposite to a direction that the main body is arched, and the straight ends are continued to the curved ends, respectively,

the curvature radius R of the main body is 5 mm to 80 mm,

a total length of the main body, the curved ends, and the straight ends is 10 mm to 90 mm,

a length of the straight end is 0.5 mm to 10 mm,

an angle of the curved end is 30° to 160°,

a tensile strength of the arched steel fiber is 500 to 2800 MPa, and

a tensile elastic coefficient of the arched steel is 200 GPa or more.

* * * * *