

PATENT SPECIFICATION

(11) 1 546 824

1 546 824

- (21) Application No. 26119/76 (22) Filed 23 Jun. 1976 (19)
(31) Convention Application No. 50/077724 (32) Filed 23 Jun. 1975 in
(33) Japan (JP)
(44) Complete Specification Published 31 May 1979
(51) INT. CL.² E04C 5/03
(52) Index at Acceptance
E1K 15



(54) STEEL BAR FOR CONCRETE REINFORCEMENT HAVING A NON-CIRCULAR CROSS-SECTION

(71) We, KOBE STEEL LTD., a corporation organised under the laws of Japan, of 3-18, 1-Chome, Wakino-hama-cho, Fukiai-ku, Kobe-city, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a steel bar or rod having a non-circular cross section for use in concrete reinforcement.

Steel bars having a non-circular cross section have widely been used in place of round bars for reinforcing concrete used in civil engineering and construction. Some of these steel bars have either only transverse ribs of various shapes disposed around the outer circumference thereof and extending in the circumferential direction, and some have only longitudinal ribs of various shapes extending in the longitudinal direction. Yet other bars have both transverse and longitudinal ribs as disclosed, for example, in United States Patent Specifications Nos. 2,374,827 and 2,377,980.

Along with progress in techniques for reducing the labour needed for construction, and the development of light-weight construction materials, prefabricated reinforcing bar assemblies of non-circular cross section have been produced on a large scale and have gained a wide application in recent years. The mass production of the prefabricated reinforcing steel bar assemblies has produced a drastic reduction in the time needed to make a given concrete construction and has improved efficiency as well as standardization of the reinforcing steel bars.

There is, however, a problem with reinforcing steel bars of this type, and this concerns the coupling or joint to be used for connecting two similar reinforcing steel bars. The ideal coupler would be one that can connect similar reinforcing steel bars easily and rapidly, absorb a considerable assembly error as well as dimensional error and yet ensure accurate and reliable connection. These requirements are of utmost importance especially for the reinforcing steel bars having a non-circular cross section. Though various coupling structures have been proposed, such as a thread-coupling system, and a pressure-sleeve system, all of them need to be adapted to commercially available reinforcing steel bars of a non-circular cross section and hence are not perfectly satisfactory.

To cope with this problem, a specific coupling structure has recently been provided for a reinforcing steel bar having a non-circular cross section *per se* thereby to simplify the coupler means, the tools and the operations involved in coupling. As typical of reinforcing bars of this type, mention can be made of a so-called threaded reinforcing steel bar in which a number of lug-forming independent transverse ribs are spaced round the outer circumference of the bar in such a manner that groups of these transverse ribs can mate with a female helical thread.

In Figures 1 to 6 of the accompanying drawings:

Figure 1 is a side view of a known threaded steel bar for concrete reinforcement;

Figure 2 is another side view of a known threaded steel bar for concrete reinforcement;

Figure 3 is a cross section through the bar shown in Figure 2;

Figure 4 is a schematic view of a roll caliber for roll-shaping a known steel bar having a non-circular cross section for concrete reinforcement;

Figure 5 also is a schematic view of another roll caliber for roll-shaping a known steel bar having a non-circular cross section for concrete-reinforcement; and

Figure 6 is a schematic view illustrating the mode of roll-shaping a known steel bar having

16

a non-circular cross section.

As shown in Figures 1 and 2 a number of transverse ribs 2 are spaced on the outer circumference of the bar 1 at a constant pitch in the longitudinal direction thereof. Each of these transverse ribs 2 has a lug-forming shape extending from the core of the bar 1, the ribs being divided into two groups 2a, 2b which are disposed on the diametrically opposite surface portions of the core of the bar 1. The groups of ribs 2a, 2b are so disposed that lugs of the ribs can mate with female threads sequentially. Reinforcing steel bars of the constructions shown in Figures 1 and 2 are disclosed respectively in United States Patent Specifications Nos. 3,782,839 and 3,561,185.

Because of the mating engagement with female threads, reinforcing steel bars of this type can be connected easily, reliably and fixedly with each other by the use of a coupler-type sleeve. In addition, the tenacity of the reinforcing steel bar itself is satisfactorily high.

As shown in the enlarged sectional view of Figure 3, the cross-sectional shape of the core of the known threaded reinforcing steel bar 1 is substantially circular except for the groups of transverse ribs 2. As shown in Figure 3, the two groups of transverse ribs 2 are disposed at opposed positions on the outer circumferential plane of the core of the steel bar. In Figure 3, the upper half of the group of ribs are shown to have an outer surface which is concentric with the core while the lower half thereof have an oval shaped outer surface.

In this instance, the transverse ribs having the top portion are disposed so as to define an independent lug-form extending in the circumferential direction of the steel bar. Because of the coupling by means of mating engagement with female threads, however, no longitudinal rib is formed on the outer circumferential plane of the core to extend linearly in the longitudinal direction of the steel bar 1. In Figure 3, the symbol 0 denotes the centre of the core of the steel bar 1.

The reinforcing bar of the above-described type is generally produced by a hot-rolling process to satisfy the requirement for standardized mass-production. In to this process, a steel bar material is first hot pressed to give it an oval or a flat hexagonal cross section and then passed through a pair of finishing rolls having a caliber as illustrated in Figure 4 or Figure 5, whereby the steel bar is shaped to give it a cross section as shown in Figure 3. The portion 3 of the caliber indicated by the full line in Figure 4 is to shape the cubic outer circumferential surface of the steel bar into a circular form while the portion 4 thereof indicated by the dotted line is to shape the transverse ribs 2 which have an outer surface concentric with the core shown in Figure 3. Likewise the portion 4a indicated by the dotted lines in Figure 5 is to shape the transverse ribs 2 having an oval outer surface shown in Figure 3.

Figure 6 illustrates the relationship between the steel bar material 1a and a pair of finishing rolls 5. During roll-shaping of the steel bar material using a pair of finishing rolls 5 having the caliber shown in Figure 4 or Figure 5, the material 1a having an oval or a flat hexagonal cross section is pressed from the top and bottom to cause material to be forced in the transverse direction. This effect is used to cause the cross section of the core of the steel bar 1 to be shaped into a circular form simultaneously with the formation of the transverse ribs 2. The reference numeral 6 represents a gap between the pair of rolls 5.

For this reason, it is necessary to control strictly the cross-sectional area of the steel bar, the rolling shape thereof, the gap between the rolls and rolling speed. Even if all these conditions are satisfied perfectly, the effective length of the transverse rib 2 (in the circumferential direction of the steel bar 1) is still only about 1/3 to 1/2 of the circumferential length of the steel bar 1 in view of the essential conditions for the reinforcing steel bars of this type such as its bonding power to concrete and the fixing of threads in coupling sections.

In other words, the effective length of the transverse ribs 2 is considerably shorter than that of previously known reinforcing steel bars of a noncircular cross section. The threaded bar of the above-described type therefore leaves unsolved problems with respect to its ability to bond to concrete and its stable and reliable fixing using screw engagement.

According to the present invention there is provided a steel bar for concrete reinforcement comprising a core portion; two sets of transverse ribs disposed respectively at diametrically opposite surface portions of the core portion, each set comprising a plurality of transverse ribs spaced at a predetermined pitch in the longitudinal direction of the steel bar and extending therefrom in planes substantially transverse to the core; and a pair of longitudinal ribs disposed on diametrically opposite surface portions of the core intermediate the sets of transverse ribs and extending from the core linearly in the longitudinal direction thereof; the radius of the core varying over its circumference such that the outer surface of each of the longitudinal ribs is no further from the axis of said steel bar than the radially outermost part of the circumference of the core, a major central portion of the top surface of each of the transverse ribs being located on the outer surface of an imaginary cylinder whose diameter is larger than that of a second imaginary cylinder having the axis of the steel

bar as its centre and the radially outermost part of the circumference of the core located on its periphery, the outer surface of a wing portion of each of the transverse ribs being so disposed that the distance from the axis thereof decreases progressively towards the radially outermost part of the longitudinal ribs, whereby the transverse ribs can mate with a female helical thread of corresponding pitch in a coupling member.

In one embodiment of the invention the height of the said longitudinal rib is in the range of 1.0 to 2.0 mm.

Preferably the height of the said transverse rib is

$$0.05D_N + 1.3 \text{ mm}, \text{ i.e. from } (0.05D_N + 0.5) \text{ mm to}$$

$(0.05D_N + 1.3) \text{ mm}$ wherein D_N is the nominal diameter of the steel bar.

The pitch (p) of the transverse rib and the height (h) thereof preferably satisfy the following relationship:

$$3 \leq p/h \leq 11.$$

The nominal diameter (D_N), the pitch (p) and the height (h) of the transverse rib preferably satisfy the following relationship:

$$1.4 \sqrt{h/D_N} \leq p/D_N \leq 2.5 \sqrt{h/D_N}.$$

The width (w) at the root of the transverse rib is preferably in the range of $0.081D_N$ to $0.30D_N$, more preferably from $0.17D_N$ to $0.30D_N$, wherein D_N is the nominal diameter of the steel bar.

The angle defined between the plane of the thread of the transverse rib and the top portion thereof (flank angle) is preferably in the range of 23 to 60 degrees.

The width of the longitudinal rib is preferably in the range of $L/36$ to $L/12$ wherein L is the nominal perimeter of the steel bar.

In Figures 7 to 16 of the accompanying drawings:

Figure 7 is a cross-sectional view of an embodiment of a steel bar in accordance with the present invention;

Figure 8 is a schematic cross-sectional view illustrating the principal section of the steel bar of this invention in comparison with that of a known steel bar;

Figure 9 is a graph illustrating the results of comparative experiments of the bondability of concrete to a steel bar of this invention and a known steel bar;

Figure 10 is a schematic view illustrating the mode of carrying out a pull-out test for the measurement of the bondability of concrete;

Figure 11 is a schematic view illustrating the definition of the height of the transverse rib of the steel bar;

Figure 12 is a graph illustrating the correlation between the disposition and shape of the transverse rib of the steel bar and the bondability to concrete thereof;

Figure 13 is a graph illustrating the bonding characteristics of concrete;

Figure 14 is a graph illustrating the correlation between the bondability of concrete to the steel bar and the pitch and height of the transverse rib of the steel bar;

Figure 15 is a schematic view illustrating the mode of carrying out a fracture test of the steel bar;

Figure 16(b) is a sectional view of the steel bar of this invention along the line a - a of Figure 16 (a).

of this invention along the line a - a of Figure 16 (a).

The steel bar shown in Figure 7 has a core 11 provided with transverse ribs 12 and longitudinal ribs 13.

Two sets of transverse ribs 12a, 12b are disposed integrally on diametrically opposite surface portions of the core 11, each set consisting of a number of transverse ribs in the nature of lug-forming projections spaced at a predetermined pitch along the longitudinal direction of the steel bar and extending in the circumferential direction around the core 11. A pair of longitudinal ribs 13 are disposed likewise at diametrically opposite surface portions of the core 11 at positions intermediate the two sets of transverse ribs 12a and 12b, the ribs 13 extending linearly in the longitudinal direction of the steel bar.

The outer surface 13a of each longitudinal rib 13 and the surfaces 11a on the outer circumferential plane of the core 11 of the steel bar which is located at the remotest position from the axis 0 of the bar are coincident with the peripheral surface of an imaginary cylinder 14 having the axis 0 as its longitudinal axis.

The major central portions 12c of the outer surfaces of the transverse ribs are coincident with peripheral surfaces of an imaginary cylinder 15 having a diameter larger than that of the above mentioned cylinder 14. The outer surface of each wing portion 12d of the transverse ribs 12 is disposed in such a manner that the distance from the axis 0 is progressively reduced towards the top portions 13a of the longitudinal ribs 13. The dimensions D_1 , D_2 , D_3 and D_4 illustrated in Figure 3 are such as to satisfy the relation $D_1 > D_2 \geq D_3 > D_4$. D_1 is the diameter of the imaginary cylinder 15; D_2 is the diameter between the outer surfaces 13a of

the longitudinal ribs 13 which may be either equal to, or smaller than, the diameter D_2 of the imaginary cylinder 14.

The two sets of transverse ribs 12a and 12b of the present steel bar are so disposed as to permit engagement with female threads in the same way as in either of the known steel bars illustrated in Figures 1 and 2.

The advantage of a threaded steel bar having specific shapes of transverse and longitudinal ribs 12, 13 in accordance with the present invention will now be explained more specifically with reference to Figure 8.

In Figure 8, the full lines indicate the contours of the transverse and longitudinal ribs as can be appreciated from Figure 7 while the broken lines indicate the contour of the transverse ribs in a known threaded steel bar (See Figure 3). The upper half of Figure 8 illustrates the case where the half of the top portion of the transverse rib is positioned on a circumference having the axis as its centre while the lower half thereof illustrates the case where the top portion of the transverse rib is positioned on the periphery of an oval shape which corresponds to the transverse ribs 2, 2 shown in Figure 3.

When only the transverse ribs 2 are roll-reduced by a pair of the finishing rolls 5 and then hot-rolled by a conventional process, the metal fills up the portion bounded by the broken lines E and thus forms transverse ribs 2 simultaneously with the formation of the substantially round core of the steel bar.

In comparison with the known process, in order to roll the longitudinal ribs 13 at the positions corresponding to the gap 6 between the pair of finishing rolls 5 as in the present invention, the ribs 13 cannot be formed unless the portion B shown in Figure 8 is greatly reduced by rolling. When the portion B is greatly reduced by rolling, a larger amount of the metal is charged into the portion A in the reactive manner through the caliber whereby the portion A is rolled to extend outwardly.

In contrast with a known threaded steel bar which does not have any longitudinal rib, therefore, the effective length of the lug 12, that is to say, the length of the thread at an effective diameter ($\Theta_1, \Theta_2, \Theta_3$ relative to Θ in Figure 3), can be made longer, and the portions A and B give an increased area to bear the pressure. Above all, both wing portions 12d of the transverse rib 12 are allowed to effectively extend transversely. Accordingly, the effective length of the thread is never as little as 1/3 to 1/2 of the perimeter of the steel bar as in a known threaded reinforcing bar, but can be increased to more than 1/2 of the same. For this reason, the coupling action as well as the fixation of the thread can be considerably improved.

Furthermore, the presence of the portions A and B as the increased pressure-bearing area enable the bonding of the bar to concrete to be improved to a marked extent.

Figures 9 and 10 illustrates the results of experiments to show the above mentioned fact, wherein sample steel bars S tentatively rolled, having longitudinal ribs of a height of 0mm, 1.0mm and 1.7mm respectively, and a nominal diameter of 25.4mm, are embedded into the central portion of a cubic block concrete C having a side length of 150mm. After the concrete is aged sufficiently to set and the compression force of the concrete reaches 270 Kg/cm², tension is applied to the steel bar. The experiments are directed to determine the relation between the mean bond stress (a value obtained by dividing this tension by the surface area of the length of the steel bar embedded in the concrete) and the amount of slip of the steel bar with respect to the concrete, i.e. Δz (which is a slip-in quantity at the free end). This experiment is generally referred to as the "pull-out test".

A steel bar having a longitudinal rib of a height of 0mm corresponds to a known threaded steel bar such as disclosed in the aforementioned United States Patent Specification Nos. 3,561,185 and 3,782,839.

The experiments reveal that the maximum mean bond stress are 91.3 Kg/cm², 102.5 Kg/cm² and 102.1 Kg/cm², respectively, for longitudinal ribs of height 0mm, 1.0mm and 1.7mm.

Accordingly, as can be seen from the diagram in Figure 9, the steel bar of the present invention provides better bonding to the concrete than the known threaded steel bar when the height of the longitudinal rib exceeds 1.0mm.

However, increasing the height of the longitudinal rib results in an increase in the value ($D_2 - D_1$) shown in Figure 7 and thus increases the extent to which the core 11 of the steel bar is oval. This leads to directionality of the steel bar during bending thereof and is not, therefore, desirable. For this reason, the height of the longitudinal rib should not exceed 2.0mm, and is preferably between 1.0mm and 2.0mm.

Figure 12 illustrates the results of pull-out tests in which the pitch p and the height h of the transverse rib of a steel bar having a nominal diameter of 25.4mm are varied. As can be seen, when the amount of slip Δz of the free end is 0.1mm, the bond stress $\tau_{0.1}$ is larger than in a known threaded steel bar provided that $p/h \leq 13$.

In this instance, the height h is an arithmetical mean value of the height h_2 of the trans-

verse rib at the central position and its height h_1 and h_3 at positions displaced by 45 degrees respectively from the axis 0 of the steel bar as shown in Figure 11 and given by the equation;

$$h = 1/3 \cdot (h_1 + h_2 + h_3)$$

In order for the bond stress $\tau_{\max}$ when the amount of slip $\Delta\epsilon$ at the free end is a maximum to exceed the mean bond stress of the known steel bar having a non-circular cross section, p/h must be less than or equal to 11. When p/h is smaller than 3, the $\tau_{\max}$ tends to decrease along with the decrease in the p/h . It is therefore desirable that the p/h satisfies the following relation:

$$3 \leq p/h \leq 11.$$

The height of the transverse rib is preferably higher as far as the bondability to concrete and the coupling of the thread are concerned. However, the height of the transverse rib is preferably lower for the handling of the steel bar so that screw thread may not be deformed. From the point of view of rolling technique, too, the height of the transverse rib is preferably low because, if not, a uniform angle of a thread surface cannot be ensured. Hence, the height h of the transverse rib should be in the following range:

$$h = 0.05D_N + 1.3 \text{ mm, i.e.,}$$

$$(0.05 D_N + 0.5) \text{ mm} \leq h \leq (0.05 D_N + 1.3) \text{ mm}.$$

The aforementioned restriction of p/h using Figure 12 is based on the concept of the conventional design criterion that the slip-in quantity at the free end be small for a given load. Recently, the design concept of ultimate strength has come to be adopted and increasing attention has been paid to the fact that the bondability of concrete is not fractured in a brittle manner.

Figure 13 is a graph in which two concrete-bonding characteristic curve for a steel bar are shown. The ordinate represents the means bond stress and the abscissa represents the slip $\Delta\epsilon$. The curve C_1 is for concrete of a brittle nature and represents the transverse rib and the longitudinal rib of the steel bar by shearing. The fracture of concrete in this manner is referred to as shearing fracture. The curve C_2 is for less brittle concrete and represents the gradual and partial fracture of the concrete between the transverse ribs of the steel bar, which is referred to as a bearing fracture.

From the aspect of the ultimate strength of the steel bar for concrete reinforcement, the ideal bonding characteristic would be one which satisfied the following two requirements, namely:

- (1) It is upright in the elastic zone Z1, and
- (2) It has a large elasto-plastic zone Z2.

It should be mentioned that the zone Z3 is the plastic zone.

On the basis of this concept, the relation between the pitch p and height of the transverse rib is determined from the results of the pull-out test to stipulate the zone where both the shearing resistance and bearing resistance relatively act simultaneously. This zone is represented by the shaded area in Figure 14. When expressed by the general formula

$$p/D_N = k\sqrt{h/D_N} \quad (k = \text{constant}),$$

the zone is expressed by:

$$1.4 \sqrt{h/D_N} \leq p/D_N \leq 2.5 \sqrt{h/D_N}.$$

The zone above the shaded area represents bearing destruction, and that below represents shearing destruction.

In an experiment in which a threaded steel bar 20 is secured to a stationary board or surface plate 21 by a nut 22 and subjected to a fracture test by applying thereto a tension as shown in Figure 15, the following relation has been confirmed necessary between the number of screw threads n width w at the root of the thread and nominal diameter D_N of the steel bar in order for the core of the steel bar to be fractured without thereby causing the fracture of the thread of the steel bar or of the nut:

$$nw \geq 1.72 D_N.$$

However, the length of the nut cannot be increased indefinitely in practice because of the serious problems in producing the nut *per se* as well as a coupler which usually has a length twice as long as the nut. In other words, there are various problems such as damage of the screw-cutting tap or bite and deterioration of quality. For these reasons, the length of the nut should be kept generally to not more than $2D_N$.

In this instance, the restriction on the width w of the transverse rib is preferably given by $w = 0.081D_N$ to $0.30D_N$

Since

$$3 \leq p/h \leq 11, \text{ and}$$

$$(0.05D_N + 0.5) \leq h \leq (0.05D_N + 1.3).$$

However, the width w is more preferably in the range of

$$w = 0.17D_N \text{ to } 0.30D_N.$$

On the basis of this restriction of the width w and the aforementioned restriction of the

26

height h of the transverse rib, the flank angle α of the thread surface of the transverse rib shown in Figure 16(b), which is a sectional view along the line $a-a$ of the plan view of Figure 16(a), is given by $\alpha \geq 23^\circ$.

5 The angle α may be larger than 23° theoretically, but it should not be more than about 60° from the point of view of rolling technique, though the value naturally varies to a certain extent depending upon the rolling speed and diameter of the roll. 5

10 So long as the area of the longitudinal rib of the steel bar is about half the allowable error of a nominal cross sectional area, various controlling operations for rolling can be omitted. This is proved by experience in rolling ordinary reinforcing bars. When the height of the longitudinal rib is from 1.0 to 2.0mm, the width thereof is preferably in the range of $L/36$ to $L/12$ (wherein L is a nominal perimeter, i.e., $L = \pi D_N$). 10

15 As has been described above, the steel bar for concrete reinforcement in accordance with the present invention not only mates with a coupler having a female thread, but also avoids the need for various strict controlling operations by means of finishing rolls such as controlling the cross-sectional area of the steel bar, the gap between the finishing rolls, the rolling speeds and the like because the area of the longitudinal ribs mitigates the error. 15

The present invention is not restricted to a steel bar for concrete reinforcement, but also could be adopted for a steel bar for prestressed concrete and anchoring bolts.

WHAT WE CLAIM IS:-

20 1. A steel bar for concrete reinforcement comprising a core portion; two sets of transverse ribs disposed respectively at diametrically opposite surface portions of the core portion, each set comprising a plurality of transverse ribs spaced at a predetermined pitch in the longitudinal direction of the steel bar and extending therefrom in planes substantially transverse to the core; and a pair of longitudinal ribs disposed on diametrically opposite 25 surface portions of the core intermediate the sets of transverse ribs and extending from the core linearly in the longitudinal direction thereof; the radius of the core varying over its circumference such that the outer surface of each of the longitudinal ribs is no further from the axis of said steel bar than the radially outermost part of the circumference of the core, a major central portion of the top surface of each of the transverse ribs being located on the 30 outer surface of an imaginary cylinder whose diameter is larger than that of a second imaginary cylinder having the axis of the steel bar as its centre and the radially outermost part of the circumference of the core located on its periphery, the outer surface of a wing portion of each of the transverse ribs being so disposed that the distance from the axis thereof decreases progressively towards the radially outermost part of the longitudinal ribs, whereby the transverse ribs can mate with a female helical thread of corresponding pitch in a 35 coupling member. 35

2. A steel bar as claimed in claim 1 wherein the height of the longitudinal ribs is from 1.0 to 2.0mm.

40 3. A steel bar as claimed in claim 1 or 2 wherein the height of the transverse ribs is from $(0.05D_N + 0.5)$ to $(0.05D_N + 1.3)$ mm in which D_N is the nominal diameter of the steel bar. 40

4. A steel bar as claimed in any preceding claim wherein the height h and pitch p of the transverse ribs satisfy the relation $3 \leq p/h \leq 11$.

45 5. A steel bar as claimed in any preceding claim wherein the pitch p of the transverse ribs and the nominal diameter D_N of the steel bar satisfy the relation $1.4 \sqrt{h/D_N} \leq p/D_N \leq 2.5 \sqrt{h/D_N}$, in which h is the height of the transverse ribs. 45

6. A steel bar as claimed in any preceding claim wherein the width of the transverse rib at the root is from $0.081D_N$ to $0.30D_N$ in which D_N is the nominal diameter of the steel bar.

50 7. A steel bar as claimed in claim 6 wherein the width of the transverse rib at the root is from $0.17D_N$ to $0.30D_N$. 50

8. A steel bar as claimed in any preceding claim wherein a flank angle defined by the thread surface of the transverse rib and the top portion thereof is from 23° to 60° . 50

9. A steel bar as claimed in any preceding claim wherein the width of the longitudinal ribs is from $L/36$ to $L/12$, L being the nominal perimeter of the steel bar.

55 10. A steel bar for reinforcing concrete, substantially as herein described with reference to Figures 7 to 16b of the accompanying drawings. 55

60 ELKINGTON & FIFE,
Chartered Patent Agents,
52-54 High Holborn,
High Holborn House,
London WC1V 6SH.
Agents for the Applicants. 60

20



height h of the transverse rib, the flank angle α of the thread surface of the transverse rib shown in Figure 16(b), which is a sectional view along the line $a - a$ of the plan view of Figure 16(a), is given by $\alpha \geq 23^\circ$.

The angle α may be larger than 23° theoretically, but it should not be more than about 60° from the point of view of rolling technique, though the value naturally varies to a certain extent depending upon the rolling speed and diameter of the roll.

So long as the area of the longitudinal rib of the steel bar is about half the allowable error of a nominal cross sectional area, various controlling operations for rolling can be omitted. This is proved by experience in rolling ordinary reinforcing bars. When the height of the longitudinal rib is from 1.0 to 2.0mm, the width thereof is preferably in the range of $L/36$ to $L/12$ (wherein L is a nominal perimeter, i.e., $L = \pi D_N$).

As has been described above, the steel bar for concrete reinforcement in accordance with the present invention not only mates with a coupler having a female thread, but also avoids the need for various strict controlling operations by means of finishing rolls such as controlling the cross-sectional area of the steel bar, the gap between the finishing rolls, the rolling speeds and the like because the area of the longitudinal ribs mitigates the error.

The present invention is not restricted to a steel bar for concrete reinforcement, but also could be adopted for a steel bar for prestressed concrete and anchoring bolts.

WHAT WE CLAIM IS:-

1. A steel bar for concrete reinforcement comprising a core portion; two sets of transverse ribs disposed respectively at diametrically opposite surface portions of the core portion, each set comprising a plurality of transverse ribs spaced at a predetermined pitch in the longitudinal direction of the steel bar and extending therefrom in planes substantially transverse to the core; and a pair of longitudinal ribs disposed on diametrically opposite surface portions of the core intermediate the sets of transverse ribs and extending from the core linearly in the longitudinal direction thereof; the radius of the core varying over its circumference such that the outer surface of each of the longitudinal ribs is no further from the axis of said steel bar than the radially outermost part of the circumference of the core, a major central portion of the top surface of each of the transverse ribs being located on the outer surface of an imaginary cylinder whose diameter is larger than that of a second imaginary cylinder having the axis of the steel bar as its centre and the radially outermost part of the circumference of the core located on its periphery, the outer surface of a wing portion of each of the transverse ribs being so disposed that the distance from the axis thereof decreases progressively towards the radially outermost part of the longitudinal ribs, whereby the transverse ribs can mate with a female helical thread of corresponding pitch in a coupling member.

2. A steel bar as claimed in claim 1 wherein the height of the longitudinal ribs is from 1.0 to 2.0mm.

3. A steel bar as claimed in claim 1 or 2 wherein the height of the transverse ribs is from $(0.05D_N + 0.5)$ to $(0.05D_N + 1.3)$ mm in which D_N is the nominal diameter of the steel bar.

4. A steel bar as claimed in any preceding claim wherein the height h and pitch p of the transverse ribs satisfy the relation $3 \leq p/h \leq 11$.

5. A steel bar as claimed in any preceding claim wherein the pitch p of the transverse ribs and the nominal diameter D_N of the steel bar satisfy the relation

$1.4 \sqrt{h/D_N} \leq p/D_N \leq 2.5 \sqrt{h/D_N}$, in which h is the height of the transverse ribs.

6. A steel bar as claimed in any preceding claim wherein the width of the transverse rib at the root is from $0.081D_N$ to $0.30D_N$ in which D_N is the nominal diameter of the steel bar.

7. A steel bar as claimed in claim 6 wherein the width of the transverse rib at the root is from $0.17D_N$ to $0.30D_N$.

8. A steel bar as claimed in any preceding claim wherein a flank angle defined by the thread surface of the transverse rib and the top portion thereof is from 23° to 60° .

9. A steel bar as claimed in any preceding claim wherein the width of the longitudinal ribs is from $L/36$ to $L/12$, L being the nominal perimeter of the steel bar.

10. A steel bar for reinforcing concrete, substantially as herein described with reference to Figures 7 to 16b of the accompanying drawings.

ELKINGTON & FIFE,
Chartered Patent Agents,
52-54 High Holborn,
High Holborn House,
London WC1V 6SH.
Agents for the Applicants.