Comparison of a Rebar with a Plain Surface and a Deformed Axis over HYSD rebars

Kishan Parmar[1], Harsh Rathod[2]

[1,2]Student, Civil Engineering Department, Institute of Technology Nirma University, INDIA

Abstract: *The paper discusses about how to overcome the early distress in concrete structures and lower bonding between concrete and steel. For this, a Rebar with a plain surface and a deformed axis for durable concrete construction is proposed which will enhance their ductility and increase its energy absorbing capacity. Various types of deformed bars and deformation techniques are discussed. The paper also suggests the application of plain surface and deformed axis rebars.*

Keywords: *Early distress, spalling of concrete, deformed axis rebars , protrusions ,surface ribs.*

INTRODUCTION:

Concrete is one of the widest used material in the construction industry having high compressive strength but is weak in tension, shear, flexure and torsion. These weaknesses are overcome with addition of the **REBARS** in case of the reinforced concrete and high strength steel wires or cables in case of the prestressed concrete. Concrete structures, built during recent decades, have been characterized by early decay and distress.

Steel is ideal for use to reinforce concrete as it is having high modulus of elasticity which is greater than that of concrete and also high thermal expansion; also advantageous due to its easy availability and less cost. CTD bars came into existence with a proof stress of 420 N/mm^2 and so on and so forth many Steel bars were introduced with its different characteristic property. Today, mostly steel with its surface having lugs or protrusions are used in order to increase the bond capacity between the rebar and the surrounding concrete but the consequence of using such a bar lead to early state of distress.

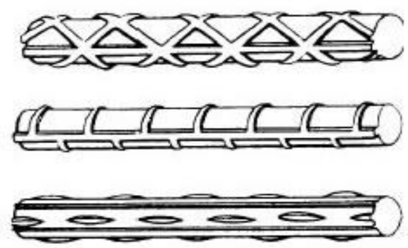


Fig 1 : Rebars prone to early corrosion leading to distress and decay in concrete.

This phenomenon of early distress in concrete structures started showing up in the decade of the 1970's, as it will be evident in a 1991 paper by Papadakis, et al who reported ; "The last two decades have seen a disconcerting increase in examples of the unsatisfactory durability of concrete structures, specially reinforced concrete ones."[1]

Many attempts were made in order to counteract the early distress in concrete like providing epoxies on the surface of the bar and various other methods but the provision of surface protection system were not economical and in some cases have to be repeated over the period of the enhanced life. It would be advantageous if REBAR with properties like having high strength per unit area with a superior bonding, not corroding early and economical.

Epoxy coated, galvanized or stainless steel rebars with the surface deformations have been attempted in these situations at greater initial expense, but Kar, Anil K., explained why at added cost epoxy coated steel rebars did not give any assurance of added life span to RC structures[13]. Furthermore, the use of epoxy coated rebars could prevent bond between rebar and surrounding concrete and it could make reinforced concrete structures especially vulnerable under vibratory load conditions as it would be during earthquakes.

HSD rebars would corrode early due to several reasons as: (1) presence of deformations on the surface of such rebars of steel cause nominal strains and stresses in such bars to rise and go past yield locally in a phenomenon known as stress concentration,(2) high yield strain, stresses beyond yield leading to slippage at intergrain faces of metal,(3) exposure of unstable and unprotected surface of steel rebar to the agents of corrosion, viz, moisture,oxygen,chlorides etc. would cause corrosion early.

OBJECTIVE:

1. To provide an improved reinforcing bar which is capable of enhancing the life span of reinforced concrete structures, constructions, elements, steel-concrete composites, etc.

2. To provide an improved bar which has a plain surface and a deformed axis.

3. To provide a REBAR of steel which, in the absence of local surface features does not have enhancement of stresses and strains locally and which does not corrode as quickly as rebars with surface protrusions or indentations do.

4. To provide an improved reinforcing bar which is cost effective, simple in configuration or concept and which is easy to manufacture and use.

5. To provide a process for the manufacture of the improved reinforcing bar.

DETAILED DESCRIPTION OF SHORTCOMINGS OF CTD REBARS

Combined effects of several stresses due to manufacturing constraints in creating lugs on the rebar surface, local enhancement of nominal stresses as an effect of stress concentration due to presence of lugs or protrusions on the surface, lack of adequate ductility, pressure and carbon content and absence of Fe_2O_3 when they are converted into HSD bars through the TMT process.

The rebar with a plain surface and the deformed axis is most suitable viz. in absence of surface lugs to provide improved resistance to slippage that an HSD rebar is likely to do.

As the bar is provided with a deformed axis which makes it looks undulating/wavy in perspective view. The amplitude and pattern as well as the distance may vary from bond or resistance to pull-out which is maintained without compromising the linear characteristic of the bar. The amplitude of the deformation of axis of the REBAR is 1 to 10mm.[1]

The present invention is directed at a process to manufacture the said product where a straight line bar is made to have a deformed shape at about 900^{o}C to 1200^{o}C.[1]

Anil K. Kar had suggested that the rate of corrosion increased with stress levels and it accelerated as stresses approached yield stress levels.[2]

In an article in ACI Materials Journal in 1991 Papadakis and others observed that the last two decades have seen a disconcerting increase in examples of the unsatisfactory durability of concrete structures, specially reinforced concrete ones.[3]

The greater vulnerability of the root regions of lugs was also recorded by Alekseev when he stated that "In accelerated tests, the durability of reinforcement specimens with a stepped (deformed) profile may be roughly an order less than that of smooth specimens since the former have space concentrators on the surface of the bases of projections which represent sites of preferential formation of cracks".[7]

Swamy remarked that "the most direct and unquestionable evidence of the last two/three decades on the service life performance of present constructions and the resulting challenge that confronts us is the alarming and unacceptable rate at which the infrastructure systems all over the world are suffering from deterioration when exposed to real environments." Swamy also mourned the "unacceptably poor performance of reinforced concrete structures in spite of the tremendous advances that have been made in understanding of the science engineering and mechanics of materials and structures."[9]

Kar observed that though other forms of HSD bars may be superior to CTD bars, stresses in the cases of such other forms of HSD rebars too would or could reach yield levels under service load conditions due to the combination of (a) residual stresses, which develop during the making of bars with surface protrusions, (b) nominal stresses under load, coupled with their enhancement in keeping with the phenomenon of stress concentration as a result of the presence of lugs or protrusions on the surface of HSD or high yield strength deformed (HYSD) rebars and (c) high stresses on lugs or protrusions which may develop due to wedge action against surrounding concrete. Also, there is a greater probability of separations developing between HSD rebars and the surrounding concrete.[4][5][6][8]

The greater vulnerability of HSD rebars from another angle was recorded also by Mohammed, et al thus :"Due to the formation of gaps, the bottom part of horizontal steel, shows significant macro cell and microcell corrosion. Deformed bars corroded more than plain bars."[10]

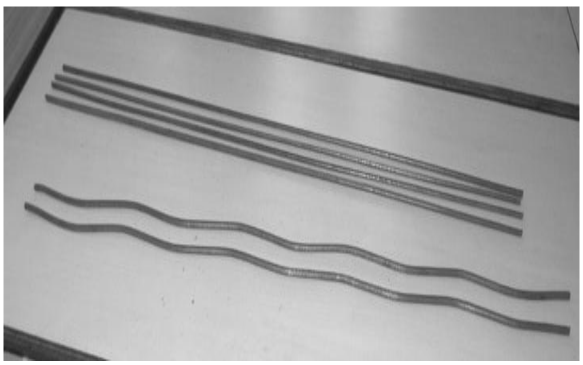


Fig2. The photographs of present rebar with plain surface and curved axis

It is not always the HSD rebars that are responsible for the early distress and decay but it also results due to surface characteristics or contour.[11]

PROCESS OF MANUFACTURING OF REBARS:

The proposed bar, with a deformed axis and a plain surface is simple in concept and configuration. It is easy to make and use. A smooth sinusoidal deformation pattern with an offset of 2 mm-5 mm from the original straight line axis and a pitch length of 10 to 50 times the diameter of the bar might be practical. The bars with deformed axes, which are shown in Fig.2, have an offset of 4.0 mm and the pitch length is 33 times the diameter.[1]

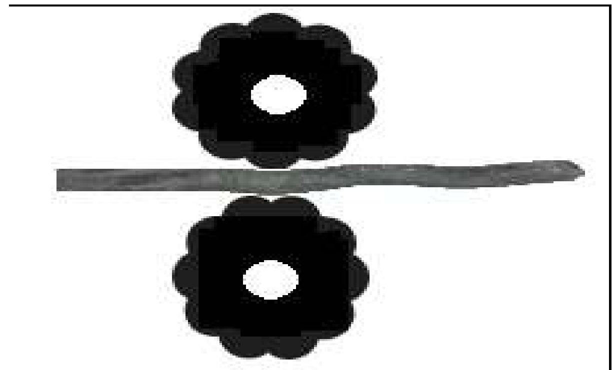


Fig3. Achieving deformed configuration of bar at rolling mill at final stand

The C-bar can have any cross section, but it shall preferably have no sharp bend, indentation or protrusion, the provision of which could cause high residual stresses to develop and the presence of which might act as stress concentrators or raisers leading to significant amplification of nominal stresses through any form of stress concentration. In short, a circular cross section will be preferred. There are no restrictions or limits to the size of C-bars.[1]

Both hot working (during plastic state of material in the region of about 900^0C to 1200^0C) and cold working are possible in the making of C-bars. In hot working processes, without or with any treatment for controlled cooling to modify metallurgical properties (e.g., an austenite core and a marten site outer layer), the gear rollers can be at the final stand of the rolling mill operations, whereas in cold working processes, the gear rollers can be at the last stage of operation, unless there will be a tempering operation for the relieving of residual stresses.[1]

A likely process diagram for a hot working process, with optional controlled Cooling/super cooling is shown in Fig.4.

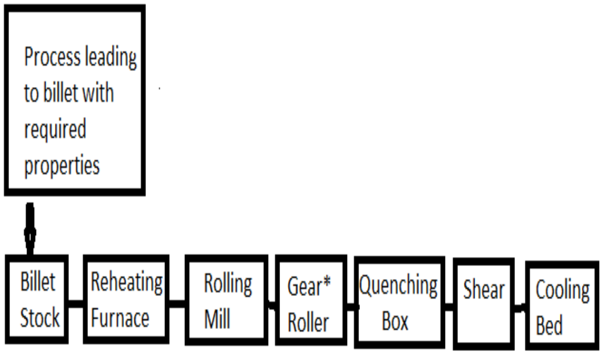


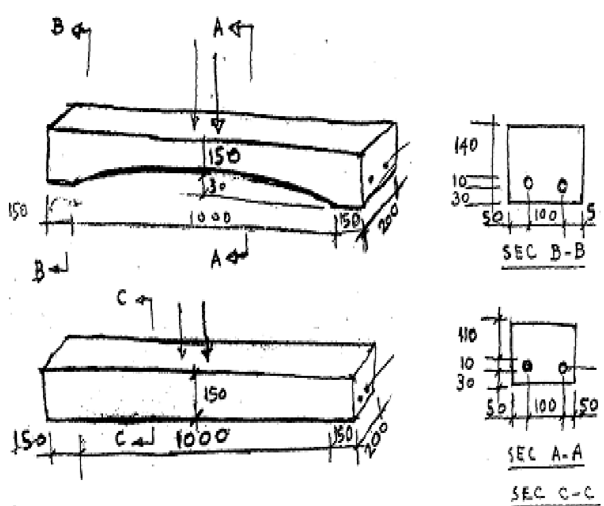
Fig4. A generalized process diagram for achieving deformed configuration of bars with optional controlled cooling (quenching)

PLACING OF REBARS AND TESTING OF SPECIMEN:

The use of C-bars could possibly make reinforces concrete structures much more ductile than the concrete structures which may be reinforced with conventional rebars.

The test beams has no ties or stirrups that could have prevent lateral thrust, if any, by the curved bars in tension due to transverse loads on the beams. Under the two-point load tests on beams with equal on beams with equal reinforcement, the crack and the failure patterns at ultimate loads were identical.

There was no sign of spalling of concrete when C-bars were used as reinforcing bars. It needs to be noted here that in order to avoid any possible confining effects of ties/stirrups, no such tie or stirrup was used in the beams.



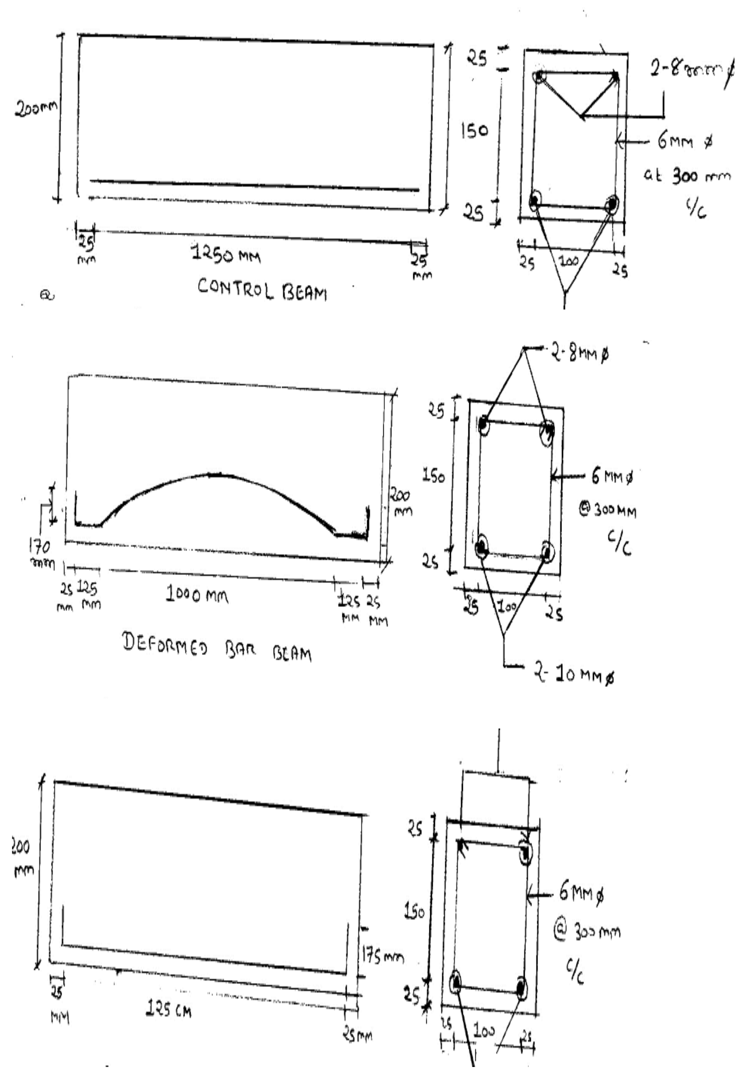


Fig5. Detailing of REBARS

Under two-point load tests on beams with equal except for differences in configuration of rebars, the crack and failure patterns at ultimate loads were identical.

Fig6. Two point load test on reinforced concrete beam.

The test results confirm that there need be no concern for any pushing out or spalling of concrete as tension in proposed C-bars (rebars with deformed axis) increases under increasing load.

Fig7.Crack pattern in beam reinforced with Proposed rebar.

Fig 8. Crack pattern in beam reinforced with plain round bars with straight axis.

PRINCIPLE ADVANTAGE OF REBARS

(a) Overcoming the principal disadvantages of HSD rebars viz., high residual stresses, stress concentration or amplification of nominal stresses, high stresses due to wedge action of lugs or protrusions and the intrinsic propensity of HSD bars for early corrosion from enhanced strain and stress levels.

(b) Limiting stresses and strains to sub-yield levels, thereby making possible the passivation of the C-bar in the alkaline environment inside concrete

(c) Lessening microcell and macro cell formation underneath and around in the case of the C-bar.

(d) Achieving economy by using medium tensile and high strength steel rebars without the need for any special treatment.

(e) Enhancing the life span of reinforced concrete structures and other constructions
Without necessarily having to make any additional effort or without having to incur any additional expenses, viz., increasing the quantities of costlier elements or adding new
materials in the making of steel, the provision of coatings to rebars or galvanizing of rebars, use of admixtures in concrete, provision of surface protection to concrete structures, etc.

(f) Lessening the demand for scarce construction materials and construction labor over the period covering the enhanced life span of structures.

(g) Lessening the impact on the environment, both because of lessened demands for new construction materials as well as lessened demands for space for the dumping of materials from a fewer fallen structures. All of the above make the C-bar a contender for replacing HSD rebars of steel.

TESTS AND FURTHER CONSIDERATIONS:

It should be evident from the presentation in the paper that the proposed bar, with its plain surface and a deformed axis, will meet the main objective of enhancing the life span of concrete Structures which otherwise might have been adversely affected by early corrosion in HSD rebars. Tests have shown that the use of the proposed C-bars will not have any adverse effects, like pushing concrete out (spalling) in the case of flexural elements. However, more tests may be conducted to determine, if the changing slope of the axis of the C-bar will lead to any Consequential change in shear forces.[1]

Tests are conducted in a single rebar whereas in most of the real cases rebars are in close proximity to each other and tensile forces in each bar affects the performance of its neighboring bars in terms of their resistance to pull out or tensile forces.

Tests will certainly be in order to determine optimum or practical offsets (excursions from the straight line axis) and pitch lengths (distance between successive peaks on the same side) of C-bars of different sizes (diameters).

In the case of beams, the C-bars may be oriented such that the planes of their bending may be conveniently made to be parallel to the plane of webs/stems of beams.

The orientation of C-bars in the case of columns require special consideration as because of small cross-sectional dimensions columns may see a small drop in their moment carrying capacities with the use of C-bars in lieu of rebars which have a straight line configuration .

Tests have been carried out at various institutes in order to conclude that proposed rebars have many advantageous characteristics in comparison to the bars used today viz. HSD bars.

CONCLUSIONS:

Compared to plain round bars of low strength low-carbon steel, HSD bars are more economical in the first instance. Reinforced concrete structures, constructed during recent decades with HSD rebars, have, however, proved to have a shortened life span. In other words, in terms of the life cycle cost a concrete construction with HSD rebars may or may not be superior to another concrete construction with plain round bars of low strength steel.

High residual stresses, additional stresses due to wedge action and amplification of nominal stresses due to the presence of surface ribs, lugs or protrusions on HSD bars have much to do with the shortening of the life span of concrete structures, built with HSD rebars.

An improved type of rebar, with enhanced resistance to slippage under tensile or pull-out forces, but relatively free from residual stresses, added stresses due to wedge action and amplification of nominal stresses that could lead to the possibility of strains and stresses rising to yield levels and beyond, and thereby to accelerated rates of corrosion, is proposed for the construction of reinforced concrete structures.

Tests have revealed that the use of C-bars in concrete elements can greatly enhance their ductility and thus lead to very significant increase in their energy absorbing capacity; all at no added cost.

The proposed rebar, with a deformed axis and a plain surface, will permit the construction of concrete structures, which will be durable and economical both in the short term as well as in the long term.

Constructions with the proposed rebars will be economical in the short term as it will be possible to use high strength steel without any surface treatment to rebars or without the use of admixtures in concrete and there will be an enhancement in the life span of concrete constructions.

REFERENCES:

[1]. KAR ,Anil Krishna ,"An improved reinforcing bar and the method for manufacturing.", September 09, 2011

[2]. Kar, A. K., "Concrete Structures - the pH Potential of Cement and Deformed Reinforcing Bars," Journal of the Institution of Engineers (India), Civil Engineering Division, Vol. 82, June 2001, Calcutta, pp. 1-13.

[3]. Papadakis, V. G., Vayenas, C. G., and Fardis, M. N., "Physical and Chemical Characteristics Affecting the Durability of Concrete," ACI Materials Journal, American Concrete Institute, March - April, 1991.

[4]. Kar, A. K., "Waterproofing of structures : Challenges and solutions," New Building Materials & Construction World, Vol. 11, Issue 10, April, 2006, New Delhi, pp. 110-128.

[5]. Kar, A. K., and Vij, S. K., "Enhancing the Life Span of Concrete Bridges," New Building Materials & Construction World, Vol. 15, Issue 6, December 2009, New Delhi, pp. 114-156.

[6]. Kar, A. K., "Deformed Reinforcing Bars and Early Distress in Concrete Structures," Highway Research Bulletin, No. 65, Indian Roads Congress, December 2001, New Delhi, pp. 103-114.

[7]. Alekseev, S. N., "Corrosion of Steel Reinforcement," Chapter 7 in Moskvin, V. (edited by), translated from the original by V. Kolykhmatov, "Concrete and Reinforced Concrete Deterioration and Protection," 1990, English translation, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, 1993, original Mir Publishers, Moscow 1990.

[8]. Kar, A. K., "Concrete Structures - the pH Potential of Cement and Deformed Reinforcing Bars," Journal of the Institution of Engineers (India), Civil Engineering Division, Vol. 82, June 2001, Calcutta, pp. 1-13.

[9]. Swamy, R. N., "Infrastructure Regeneration : the Challenge of Climate Change and Sustainability - Design for Strength or Durability," The Indian Concrete Journal, The ACC Ltd., Vol. 81, No. 7, July 2007, Mumbai.

[10]. Mohammed, T.U., Otssuki, N., and Hisada, M., "Corrosion of Steel Bars with respect to orientation," ACI Materials Journal, American Concrete Institute, March-April, 1999.

[11]. Kar, A.K., Deformed Rebars in concrete construction, New building materials & construction world, December 2006, Vol. 12, No. 6

[12] ("FBEC rebars must not be used."The Indian concrete Journal, Vol. 78, No.1, January 2004)