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⑤④ **Concrete reinforcing bar.**

⑤⑦ Concrete reinforcement is provided by means of stainless steel bar which has been cold worked by twisting. Austenitic stainless steel is most suitable but ferritic stainless steel may also be used. Even when a low molybdenum content of between 0.25% and 0.5% is used the resistance to corrosion and particularly chloride ion attack is satisfactory for concrete reinforcement requirements.

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Concrete reinforcing bar

This invention relates to steel bar or rod for concrete reinforcement and to the production of such bar and rod. The invention also extends to reinforced concrete incorporating such reinforcing bar or rods.

5 It is conventional to refer to larger diameter lengths of concrete reinforcement as bars and to refer to smaller diameter lengths, which are normally coiled, as rods. Throughout this specification and the claims the term "bar" is used to refer to both bar and rod material.

10 Corrosion of steel reinforcement is considered to be one of the most important causes of deterioration of reinforced concrete. Extensive corrosion problems have occurred in various parts of the world, due particularly to chloride ion attack, for example the effect of de-icing salts on bridge decks and the effect of high chloride concentrations in aggregates used for construction in some parts of the  
15 world. A wide range of methods for preventing corrosion of normal reinforcing steels have been studied none of which have satisfactorily solved the problems.

It is well known that there are currently available a variety of stainless steel materials which exhibit a high resistance to corrosion.  
20 These materials are mainly austenitic stainless steels which hitherto have been unsuitable for reinforcing concrete because of their low strength.

In attempts to make use of stainless steel in place of more conventional steels in the reinforcement of concrete, typical ferritic  
25 and austenitic stainless steel bars have been considered unsuitable because of their low strength. One proposal for solving this problem was a composite bar incorporating a core of a typical reinforcing steel within a sleeve of corrosion resistant stainless steel. The cost and difficulty of forming a stainless steel tube with an internal diameter  
30 which will just accept a reinforcing steel bar and hot rolling the resulting composite to reduce the diameter and unite the two materials

makes this an unattractive proposal.

For normal reinforced concrete applications, bars are required to have a yield strength of up to  $500 \text{ N/mm}^2$  with a minimum excess of tensile strength over yield strength of 5% and a minimum elongation value of 12%. These properties are achieved with normal carbon steels either by alloying, thermo mechanical treatment or cold working by twisting or drawing.

The present invention sets out to provide a high yield strength concrete reinforcing bar of stainless steel.

According to one aspect of the present invention a concrete reinforcing bar is characterised in that the bar is formed from stainless steel which has been cold worked by twisting.

In situations where resistance to corrosion from chloride ions is required, it is conventional to incorporate in the stainless steel a substantial proportion of molybdenum, for example about 2.5% molybdenum. A small proportion of molybdenum, for example 0.3%, is also useful in stainless steels to prevent brittleness. It has now been discovered that satisfactory corrosion resistance can be obtained in the stainless steel reinforcing bars of the invention without the large proportion of molybdenum normally associated with a chloride ion resistant stainless steel. Thus a reinforcing bar in accordance with the invention may have a molybdenum content of less than 0.5%, preferably from 0.25% to 0.5%.

The primary constituents (in addition to iron) for a stainless steel suitable for use with the present invention is as follows :-

Carbon	0.15% max
Manganese	2.0% max
Chromium	11.5% to 20%
Molybdenum	0.5% max
Nickel	7% to 12%

The invention also extends to a reinforced concrete structure

incorporating cold twisted stainless steel concrete reinforcing bars as specified above.

The invention also extends to a method of producing a concrete reinforcing bar by cold twisting an as rolled stainless steel bar.

5           The invention will now be described in greater detail in conjunction with preferred embodiments described in the following examples.

In order to provide a concrete reinforcing bar, a stainless steel material conforming to the following analysis range is selected :-

	Carbon	0.15% max
10	Silicon	3% max
	Manganese	2% max
	Phosphorus	0.04% max
	Sulphur	0.04% max
	Chromium	11.5% to 20%
15	Molybdenum	4% max - preferably 0.25 - 0.5%
	Nickel	12% max - preferably 7% - 12%
	Niobium	1% max
	Titanium	1% max
	Nitrogen	0.25% max
20	the balance being made up of iron and usual impurities.	

The stainless steel material is hot rolled in a rolling mill to the required diameter for a reinforcing bar, typically to a diameter of between 6mm and 25mm but diameters outside this range can also be used. The bar may be of circular cross-section with either a smooth outer  
 25 surface or a ribbed outer surface. Other cross-sectional shapes may be employed if desired.

After cooling to ambient temperature the bar is cold twisted in a conventional manner. The pitch of the twisting should normally be between 8 and 12 bar diameters and 10 bar diameters constitutes a convenient pitch. The cold twisted bar then constitutes a suitable stainless steel concrete reinforcement bar.  
 30

The following examples give further details of suitable stainless steel reinforcing bars in accordance with the invention.

Example 1 An austenitic stainless steel has the following analysis :-

5	<u>C</u>	<u>Si</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Cr</u>	<u>Mo</u>	<u>Ni</u>
	.03	.43	1.62	.023	.030	17.6	2.45	12.24%

This steel was hot rolled to a diameter suitable for concrete reinforcement. Mechanical properties of one sample of bar in the as rolled condition were measured. A second sample of the bar was cold twisted with a pitch equal to 10 diameters and was subjected to the same mechanical tests. Details of the mechanical properties of the two bars were as follows :-

<u>Material</u>	<u>0.2% Proof Stress (PS)</u> N/mm <sup>2</sup>	<u>Tensile Strength (TS)</u> N/mm <sup>2</sup>	<u>TS - PS</u> <u>PS</u>	<u>Elongation</u>
15 As rolled	271	577	113%	61%
Cold Twisted	660	780	18%	28%

It can be seen that the effect of the cold twisting is to increase the 0.2% proof stress very substantially and also to increase the tensile strength. The excess of tensile stress over proof stress decreases with cold working but still remains at a satisfactory 18%. Similarly, the elongation on fracture reduces after cold twisting but still remains satisfactory.

Example 2 The procedures for Example 1 were repeated but with a steel having the following analysis :-

25	<u>C</u>	<u>Si</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Cr</u>	<u>Mo</u>	<u>Ni</u>
	.05	0.25	1.58	0.026	0.011	18.70	0.39	8.30%

The mechanical properties for this steel were as follows :-

<u>Material</u>	<u>0.2% Proof Stress (PS)</u> N/mm <sup>2</sup>	<u>Tensile Strength (TS)</u> N/mm <sup>2</sup>	<u>TS - PS</u> <u>PS</u>	<u>Elongation</u>
30 As rolled	224	638	185%	61%
Cold Twisted	684	916	34%	23%

This material also exhibits a satisfactory increase in proof stress on cold twisting together with satisfactory values for the excess of tensile strength over proof stress and elongation.

Example 3 The procedures for Examples 1 and 2 were repeated with a steel having the following analysis :-

<u>C</u>	<u>Si</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Cr</u>	<u>Mo</u>	<u>Ni</u>
.11	.59	1.14	.028	.019	17.85	0.31	8.25%

In addition to a sample twisted to a pitch of 10 diameters two further samples were twisted to pitches of 11 and 12 diameters respectively. The following table illustrates that satisfactory properties were obtained and that these properties vary very little with changes in the pitch of twist.

	<u>Pitch</u> <u>(diameters)</u>	<u>0.2% Proof Stress</u> <u>(PS)</u> <u>N/mm<sup>2</sup></u>	<u>Tensile Strength</u> <u>(TS)</u> <u>N/mm<sup>2</sup></u>	<u>TS - PS</u> <u>PS</u>	<u>Elongation</u>
15	10	560	785	39%	43%
	11	560	780	39%	50%
	12	545	770	41%	50%

Example 4 The procedures for Examples 1 and 2 were repeated for a ferritic stainless steel having the following analysis :-

<u>C</u>	<u>Si</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Cr</u>	<u>Mo</u>	<u>Ni</u>
.03	.41	.24	.018	.024	18.2	2.26	0.23%

The mechanical tests on this material gave the following results:-

<u>Material</u>	<u>0.2% Proof Stress</u> <u>(PS)</u> <u>N/mm<sup>2</sup></u>	<u>Tensile Strength</u> <u>(TS)</u> <u>N/mm<sup>2</sup></u>	<u>TS - PS</u> <u>PS</u>	<u>Elongation</u>
25 As rolled	405	480	18%	38%
Cold twisted (18 diameters)	550	580	5%	20%

This is an example of a ferritic stainless steel. An adequate proof stress was achieved but even with the cold twisting limited to a pitch of 18 diameters the excess of tensile strength over proof stress

is only marginally satisfactory for reinforcing bar requirements.

In all of the above examples the cold twisted bars have a resistance to corrosion by chloride ions in sodium chloride which is satisfactory for reinforcing bar purposes. Some surface pitting can occur, particularly with the low molybdenum stainless steels. However this degree of corrosion appears to be within acceptable limits having regard to the requirements of concrete reinforcement. The strength of the reinforcing bars should not reduce to unacceptable levels during the normal life of a concrete structure, even for structures such as bridges which are subjected to dynamic loading. Similarly, the increased volume of corrosion products in the locality of the reinforcement is insufficient to create a serious risk of concrete crumbling away from the reinforcement near the surface of a structure.

Although the cost of any stainless steel is much higher than that of conventional steels used for reinforcement, the cost of certain stainless steels is not prohibitive when compared with the cost of generally unsatisfactory procedures now in use to guard against corrosion attack of conventional reinforcing bars. In particular, cold twisted low molybdenum stainless steels have a cost which is of the order of one quarter to one half of the cost of high strength high molybdenum austenitic stainless steels which might have satisfactory properties for reinforcement bar in the as rolled condition.

The cold twisted stainless steel bars described in the examples also have good impact properties making them particularly suitable where dynamic loading conditions are likely.

## Claims:

1. A concrete reinforcing bar characterised in that the bar is formed from stainless steel which has been cold worked by twisting.
2. A concrete reinforcing bar according to Claim 1 characterised in that the stainless steel contains less than 0.5% molybdenum.
3. A concrete reinforcing bar according to Claim 2 characterised in that the molybdenum content is between 0.25% and 0.5%.
4. A concrete reinforcing bar as claimed in Claim 1 characterised in that the stainless steel is an austenitic stainless steel comprising :-

10	Carbon	0.15% maximum
	Manganese	2.0% maximum
	Chromium	11.5% to 20%
	Molybdenum	0.5% maximum
	Nickel	7% to 12%
- 15 5. A reinforced concrete structure incorporating concrete reinforcing bars according to any preceding claim.
6. A method of producing a concrete reinforcing bar by cold twisting an as rolled stainless steel bar.



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 2)
X	CHEMICAL ABSTRACTS, vol. 84, 1976, page 259, no. 109501z, Columbus Ohio (USA); & JP - A - 74 131 910 (SHINDO KOSEN CO., LTD.) (18-12-1974) *Abstract*	1	E 04 C 5/01
Y	----- GB-A- 240 561 (BURNEY) *Claims 1,6*	1	
Y	--- GB-A-1 201 031 (G.K.N. SOUTH WALES LTD.) *Claim 1; page 1, lines 80-86; page 2, lines 71-80*	1	
Y	--- FR-A-1 390 625 (S.A. COCKERILL-UGREE) *Abstract 1*	1	
A	--- CHEMICAL ABSTRACTS, vol. 92, 1980, page 259, no. 80515j, Columbus Ohio (USA); & JP - A - 79 106 015 (DAIDO STEEL CO.) (10-08-1979) *Abstract*	1	E 04 C 5/01 C 04 C 5/02 C 22 C 38/44 C 22 C 38/40
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 21-06-1982	Examiner LIPPENS M.H.
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		& : member of the same patent family, corresponding document	