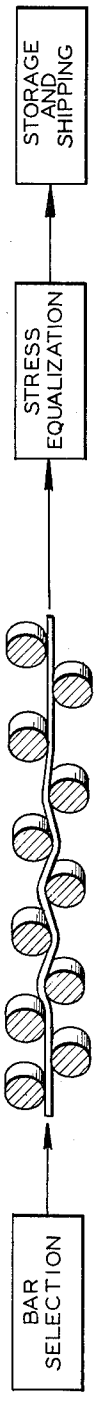
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METHOD OF PRODUCING STEEL BARS

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METHOD OF PRODUCING STEEL BARS

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The invention relates to a process for producing steel bars destined for use in pre-stressed and post-tensioned concrete structural members and, more particularly, to a method of producing steel bars capable of meeting specifications, currently widely used, relating to such concrete structural members.

Prestressed concrete is no longer considered a unique and interesting construction technique. The experience of practical use has made it an accepted medium for many types of structures. In the face of rising construction costs, engineers and designers are forced to seek a better way to attain greater benefits from materials and labor. Prestressed concrete is a step in that direction. Among the numerous applications of prestressed concrete construction are highways, bridges, tanks, retaining walls, piles, piers and posts.

The specifications which must be met in such applications are rather stringent, particularly with respect to the steel bars or rods used in the concrete structural members.

Perhaps the two main requirements of the steel bars used in prestressed concrete construction are a relatively high tensile strength combined with good ductility. These two properties are, in a manner of speaking, inconsistent, and their combination, in a single piece of material, has heretofore been economically and technically as difficult of attainment as its realization has been desirable.

It is therefore an object of the invention to provide a method of producing steel bars which have a relatively high tensile strength combined with good ductility.

It is another object of the invention to provide a method of producing steel bars meeting the specification currently widely in use in the fabrication of prestressed concrete structural members.

It is yet another object of the invention to provide a method of economically producing steel bars having desired characteristics and properties for use in concrete structural members, both in respect to pre-stressed and post-tensioned applications.

It is still another object of the invention to provide a method of producing steel bars in which the requirement of proof-stressing the bars to at least 90 percent of the minimum ultimate tensile strength of 145,000 pounds per square inch (as required by many specifications) is accomplished by and is inherent in the method itself, thus eliminating a separate and distinct testing step.

It is a further object of the invention to provide a method of producing steel bars which eliminates the necessity of a heat treatment in order to effect "stress-relief."

It is still a further object of the invention to provide a method of producing steel capable of meeting rigid specifications from hot rolled bars.

It is yet a further object of the invention to provide a method of producing steel bars in which the apparatus used in conjunction with the method is substantially standard.

It is another object of the invention to provide a generally improved method of producing steel bars for use in concrete structural members.

Other objects, together with the foregoing, are attained in the method described in the following description and shown, partially diagrammatically, in the accompanying drawing in which the various steps, or stations, are depicted.

In the production of steel bars for pre-stressed, as well as post-tensioned, concrete, certain physical properties are required, and most specifications call for relatively high tensile strengths as well as a satisfactory ductility. Exemplary of such specifications are those which call for a minimum ultimate tensile strength of 145,000 pounds per square inch, after a proof-stressing to at least 90 percent of the foregoing amount, and a minimum yield stress, at 0.2 percent offset from tangent, of 130,000 pounds per square inch. Ductility is ordinarily expressed in terms of elongation and cross-sectional area reduction, such values as 4 percent minimum elongation at rupture in twenty diameters, and 20 percent minimum reduction of area at rupture being conventional.

Ordinary hot rolled carbon steel bars with sufficient carbon content to meet these high tensile requirements lack sufficient ductility and, as a consequence, other alloying elements must be added to establish a satisfactory relationship between strength and ductility.

As is well known in the art, the basic strength of a steel bar is dependent upon the chemistry of the bar material plus the variations resulting from differences in cross-sectional area, finishing temperature, rate of cooling and normal chemical segregation. For a given bar size, a number of bars having been hot rolled in large lots at one time, the main variable as between bars will be chemical segregation. In order to minimize the effect of this variable it is necessary to restrict the chemical constitutents to rather narrow ranges. It has been found that even with this restriction, however, some variation in the tensile strength of the various bars can be expected in any given shipment from a hot-roll mill. Consequently, the minimum of the chemistry required of the mill must be sufficient to obtain, for all of the bars, tensile strength values which, upon subsequent cold working, later to be described, will meet the required specifications.

Although the method of the invention is not restricted thereto, it has been found that a steel bar selected as having, for example, the following percentage chemical analysis, provides a highly satisfactory result:

Carbon	0.68–0.75.
Silicon	0.20–0.35.
Phosphorus	0.040 maximum.
Iron	balance.
Manganese	0.90–1.20.
Chromium	0.90–1.20.
Sulfur	0.040 maximum.

The first step of the process is indicated in the drawing, therefore, as selection, the term referring to the procedure wherein hot-rolled bars having a predetermined chemical analysis and predetermined physical properties are obtained and made ready for the subsequent steps in the process. Hot-rolled bars having the following physical properties have been used with outstandingly successful results:

Tensile strength, 155,000 p.s.i.; yield point, 95,000 p.s.i.; 8 percent elongation in 10 inches; 30 percent reduction of area; and 28,000,000 modulus of elasticity.

The art recognizes that hot-rolled bars in the as-rolled condition exhibit a definite "yield point," at which point the steel takes a permanent "set," a condition which is undesirable for prestressed concrete applications. Cold working of the bars eliminates this "yield point" and produces a uniform stress-strain diagram on which "yield strength" can be ascertained by the well-known "offset method."

Since the specifications call for minimum yield strengths in terms of the offset method, cold working of the hot-rolled bars is effected, the cold working causing an increase in ultimate tensile strength of from 5,000 to 25,000 pounds per square inch.

Cold working it has been found, is most effectively

performed by alternately and repeatedly placing the outer fibers, or portions, of the hot-rolled bar in tension and compression, and, more particularly, by cold working the bar in such a fashion that the outermost fibers are "worked" the most, and the innermost, or axially located, fibers the least.

As can be seen most clearly by reference to the drawing, the step of cold working in this fashion has been very successfully accomplished by passing the bar through a mill having a plurality of rolls, alternate rolls being vertically overlapped or offset to effect an undulatory path, shown considerably exaggerated in the drawing. It has also been found that an especially uniform and desirable cold working is achieved by rotating the bar about its own longitudinal axis as the bar makes its pass through the mill. Appropriate skewing and mounting of the rolls, in a manner well known in the art, is a preferred manner of producing such rotation.

It will be understood that the particular cold-working procedure above described, in which localized portions of the bar are subjected to various tensile and compressive strains while the bar is being axially rotated, tends to leave various combinations of tensile-compressive residual stress in these localized portions of the bar. Cold working of the bars also and correspondingly decreases their ductility roughly proportionately to the amount of cold work and, in some cases, may reduce the ductility below the specification requirements. In order to increase the ductility after the cold working it is necessary to relieve or equalize some of the stresses within the steel. I prefer to use the terms "stress equalization" or "stress modulation" rather than "stress relieving" since the latter term often connotes or might be construed as relieving all of the stresses, with a consequent return to a definite "yield point" characteristic of hot-rolled material. The step I now describe partly relieves at least the greater residual stresses that may be present in localized portions of the bar, or in other words, modulates or equalizes the stresses of these portions with respect to other portions, thus insuring that all the stresses in the bar fall within a certain range of magnitude; and my process concurrently increases the lowest ductilities to equalize them with respect to the higher ductilities of the less-stressed zones, so that ductility in the bar varies from zone to zone only within a tolerable range of magnitude having a minimum value corresponding with that provided in the relevant construction specifications.

I have found that by stressing the bars uniformly to slightly under their ultimate tensile strength, and holding the bars at this stress for substantially from one to five minutes, equalization of the previously imparted cold work stresses is obtained. It has been found, as well, that by subjecting the bars to a tensile effort amounting at least to 90 percent of the ultimate tensile strength, for a period of one to five minutes, not only is the necessary equalization of stresses obtained but the customary specification requirement of "proof stressing" is concurrently met. In other words, two desirable conditions are obtained in the one step of stress equalization.

At the conclusion of the equalization procedure, the resultant bars are found to possess, for example, the following, highly desirable physical properties;

Tensile strength, 169,000 p.s.i.; Yield strength (0.2 percent offset) 135,000 p.s.i.; 7 percent minimum elongation in 10 inches; 27 percent reduction of area; and 25–27,000,000 modulus of elasticity. The foregoing values are exemplary of the properties obtaining in bars actually produced in accordance with the method of the invention, and such values are well within the requirements of even the most rigid of present-day specifications.

It can therefore be seen that I have provided a process for producing steel bars quickly and economically, and especially for producing bars highly suitable for use in the rapidly growing field of pre-stressed concrete structures.

What is claimed is:

1. The method of producing steel bars which comprises the following steps:

(*a*) selecting a hot rolled steel bar having substantially the following chemical analysis:

Silicon	0.20–0.35.
Phosphorus	0.040 maximum.
Carbon	0.68–0.75.
Iron	balance.
Manganese	0.90–1.20.
Chromium	0.90–1.20.
Sulfur	0.040 maximum.

and having substantially the following physical properties:

Tensile strength	155,000 pounds per square inch.
Yield point	95,000 pounds per square inch.
Elongation	8 percent in 10 inches.
Reduction in area	30 percent.
Modulus of elasticity	28,000,000.

(*b*) then cold working said bar by bending successive portions of said bar transversely back and forth in amounts comparable to the diameter of said bar beginning at one end of said bar and progressing toward the other end of said bar and simultaneously rotating said bar about the nominal longitudinal axis thereof;

(*c*) and finally stressing said cold worked bar by holding said bar at least at ninety percent of the ultimate tensile strength thereof for a period of one to five minutes.

2. The method of producing steel bars which comprises the following steps:

(*a*) selecting a hot rolled steel bar;

(*b*) next cold working said bar by bending successive portions of said bar transversely back and forth in amounts comparable to the diameter of said bar beginning at one end of said bar and progressing toward the other end of said bar while simultaneously rotating said bar about the nominal longitudinal axis thereof;

(*c*) and after said cold working then stressing said bar by holding said entire bar at least at ninety percent of the ultimate tensile strength thereof for a period of from one to five minutes.

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