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A STRUCTURAL STEEL

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In iron building and bridge construction there has in recent times arisen a growing demand for a steel that has a higher tensile strength and particularly a greater elasticity than is possessed by the soft flux steel almost exclusively in use up till recent times (known as standard structural steel). The harder structural steel is however required to have not only good tensile and elastic values, but at the same time good expansion and toughness, and furthermore it should not be substantially more difficult to treat than the standard structural steel. An attempt has been made to meet this need in some measure for a harder structural steel by increasing the carbon content. With the so-called carbon steel, a tensile strength of 48 to 58 kg. per sq. mm. and an elastic limit of 29 kg. per sq. mm. are obtained. The increase in the carbon content produces however a number of disadvantages which have their cause in the nature of this element of the alloy. When adding carbon to form the alloy, every increase in the elastic limit and in the tensile strength involves a considerable reduction in expansion and toughness. At the same time the tensile strength is increased to a greater extent than is the elastic limit, so that the ratio of elastic limit to tensile strength, which at the present time is much employed as the test of quality, becomes smaller as the carbon content increases. Furthermore narrow limits have been placed on an increase in the carbon content in structural steel by the need for a metal that can be well treated. Even with carbon steel with tensile strength of 48–58 kg./mm.^{2} certain difficulties are encountered in making iron bars of large cross section. Moreover in riveting work the higher carbon content has proved to be a disadvantage as the rivets made of said carbon steel have already shown themselves to be appreciably temperable.

All attempts to replace the carbon in structural steel by other strength-increasing elements of the alloy have failed generally by reason of the too high cost of the added substances. In using nickel steel for instance, the saving in the construction by reduction in weight is consumed by the too high cost of the nickel steel.

The effort to obtain the economic optimum has, in recent times, led to the use in structural steel of the strength-raising action of silicon. The silicon structural steel which is mainly employed on railways, has approximately the carbon content of the standard structural steel, but a silicon content of 1%. In this steel an elastic limit of about 36 kg. per sq. mm. is obtained with a tensile strength of at least 50 kg. per sq. mm. while the expansion is only a little less than that of said standard structural steel.

The metallurgical nature of the raw steel is not, however, inappreciably changed by the addition of 1% of silicon. The viscosity of the bath increases. This fact necessitates the very exact retention of certain mold temperatures. During solidification relatively deep fissures appear in the casting; its capacity for welding is reduced, so that the finished work often shows flaws and fissures, and the formation of tongues and scale, which often makes it doubtful whether it can be used at all and even at times renders its use entirely out of the question. Furthermore the silicon content increases the upper conversion point (A_3 point) and thus greatly limits the range of temperatures available for moulding with heat. Thus in rolling silicon steel the danger very easily arises that it will not be possible to complete the moulding with heat close above the upper conversion point—this, as is generally known acts as a guide for all moulding with heat—but it will be necessary to finish rolling the work within the critical range of temperatures thus exercising an unnatural stress upon its physical properties. Thus in silicon steel the strength values, more particularly the elastic limit, is made dependent in very large measure upon the strength of the rolled product and the rolling final temperature. Thus although the use of silicon steel represents an advance in the art, its production and use involve very great difficulties.

My experiments have shown that it is possible to produce a structural steel which is substantially free from nickel and which, on the one hand meets the need for a high elastic limit and great toughness, but on the other hand, does not exhibit the undesirable properties of silicon steel during casting and in connection with moulding with heat. The few advantages of silicon steel—low carbon content and a high capacity for being treated—are shown in large measure by the structural steel of the invention.

To obtain this, copper and chromium are added together in certain quantities to a soft flux steel having at most a 0.2% content of carbon. It has been found advantageous to keep the elements within the following limits

Cr	Cu
0.25–0.5%	0.5–1.5%

The strength-raising action of the copper has long been known but it cannot be used in practise because by experiments it has been found that the increase in the elastic limit and tensile strength as the result of the addition of copper is always combined with a very appreciable reduction in expansion and toughness.

One consequence of the simultaneous addition of copper and chromium is that there is in the present case no loss in toughness. It has already frequently been attempted to employ a copper content, for example the attempt has been made to replace a part of the nickel in nickel chromium steel by copper. These experiments have however been unsuccessful as is shown more especially from the investigations conducted by Oertel and Leveringhaus ("Der Einfluss von Kupfer auf die Eigenschaften eines Nickel-Chrom-Baustahles"—Werkstoffausschussbericht No. 35). The compounds selected by these experimenters differed from the structural steel of the invention by reason of the fact that in addition to higher carbon content there were always definite quantities of nickel. According to applicants researches and experiments, nothing is altered in the essential qualities of the structural steel according to the present invention if, to the additions mentioned of Cu and Cr, there is also added such a definite amount of Ni.

It has also been shown that the steel of the invention shows a considerable lowering of the upper conversion point—by about 100° C.—by reason of its high copper content. This lowering of the upper conversion point has the advantage that the range of temperatures available for moulding with heat is considerably increased and that thus the difficulties that arise during treatment, for example of the silicon structural steel, are removed. In addition thereto, the steel produced according to the invention has a greater resistance to corrosion by reason of its high copper content, which is well known of steel containing copper. On the other hand, it is novel that the steel of the invention has, by reason of the quality of its alloy, a resistance to scaling, which is considerably greater than that of steel alloyed only with copper.

As already stated it is of great importance in connection with the properties of the steel produced according to the invention, to maintain the carbon content low, that is to say not above about 0.2% where there is an addition of copper, the effect of which outweighs that of the chromium. Where the chromium and carbon content is greater, it is possible to obtain useful tensile values. However, the ability to harden the steel is very considerably raised so that already in the rolled condition treatment with cutting tools involves difficulties. Great weight must be placed upon the ability to operate on the material with cutting tools as experience with silicon structural steel has taught, more particularly in the case of structural steels having regard to the economy of its use.

In the new steel the sum of the two constituents—copper and chromium—shall not substantially exceed 2%. This new steel may contain, besides the above stated amounts of Cu and Cr, small amounts of Ni, W, Mo, Ti and V, not exceeding 1% respectively, without interfering with the useful action of the combined action of Cu and Cr, i. e. without lowering the essential physical qualities imparted to the steel by said action.

It may equally contain small amounts of Si and Mn, not exceeding 0.6% respectively. As example of said last case, the following composition may be given:

C	Si	Mn	Cr	Cu
0.13	0.25	0.60	0.46	1.05

For such a structural steel, the essential physical properties have on an average the following values

Dimensions of rolled metal in mm.	Treatment	Elastic limit kg. per sq. mm.	Tensile strength kg. per sq. mm.	Expansion per cent	Cutting per cent	Ratio of elastic limit to tensile strength per cent	Notched bar test mm./kg. sq. cm.
1180 x 18	Rolled condition.	38	54	23	48	70	10
1 NP 45	Rolled condition.	38	53	22	43	72	------
1180 x 18	Annealed	39	54	24	54	72	10
1 NP 45	Annealed	39	54	23	49	72	------

What I claim and desire to secure by Letters Patent of the United States is:

1. A structural steel having a low A_3-point, a high elastic limit and considerable toughness, containing about 0.1 to 0.2% carbon, and copper and chromium totaling 0.75 to 2.%, the ratio of copper to chromium being comprised between 1 to 1 and 3 to 1.

2. A structural steel having a low A_3-point, a high elastic limit and considerable toughness, containing about 0.1 to 0.2% carbon,

0.5 to 1.5% copper and 0.25 to 0.5% chromium.

3. A structural steel having a low A_3-point, a high elastic limit and considerable toughness for building iron structures containing about 0.1 to 0.2% carbon, 0.5 to 1.5% copper, 0.25 to 0.5% chromium and nickel, tungsten, molybdenum, titanium and vanadium in amounts up to 1% each.

4. A structural steel having a low A_3-point, a high elastic limit and considerable toughness for building iron structures containing about 0.1 to 0.2% carbon, 0.5 to 1.5% copper, 0.25 to 0.5% chromium and manganese and silicon in amounts up to 0.6% each.

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