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Reinforcement Related for Construction in Seismic Active Regions. Aspects of Production, Application and Control

Ivchenko AV*

Ukrainian State University of Science and Technologies, Ukraine

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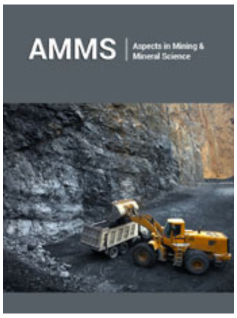

***Corresponding author:** Ivchenko AV, Ukrainian State University of Science and Technologies, Ukraine

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Abstract

At the beginning of 2023, the world was shocked by a catastrophic earthquake that occurred in Turkey and Syria. A huge number of victims and tens of thousands more injured as a result of large-scale destruction of buildings. At the same time, the destruction of houses occurred in many cities and in vast areas. We have seen all this from numerous news feeds in the media. However, it is enough to watch 3-5 videos to come to the conclusion that a large number of dead and injured is the result of the lack of reinforcement of buildings or the use of reinforcing bars of an inappropriate strength class and low quality. There are colorful examples (video from surveillance cameras) when houses simply crumbled and folded, as if they lacked reinforcement. At the same time, in the photo of the consequences of the earthquake, you can see that among the many collapsed buildings nearby are the surviving buildings. The latter indicates that the development was carried out according to different building codes using reinforcement of various strength and quality classes, or even its absence. All of the above suggests that, in the light of what happened, it is necessary to rethink the requirements for rebar for construction in seismically active regions, approaches to its production, application and control of mechanical properties.

Modern requirements for rebar to reinforcing bars are set out in national and interstate regulatory documents of various countries [1,2], which regulate the chemical composition of the steel used and the level of mechanical properties. The main characteristics that determine the applicability of reinforcing bars in construction are strength indicators-tensile strength (σ_{in}) and yield strength ($\sigma_{0.2}$), and deformability-relative uniform elongation (δ_p) or total relative elongation at maximum load (δ max). The level of the last characteristic is differentiated into three groups [1], which determines the applicability of rein-forcing bars for critical structures, depending on climatic and seismic conditions. For reinforcing bars with a strength of 400-600MPa, there are three categories of deformability-standard (δ_{max}≥2.5%), increased (δ_{max}≥5.0%) and high (δ_{max}≥7.5%)*. The practice of using reinforcing bars in structures for special purposes, or construction in different climatic regions, takes into account the use of bars with different levels of deformability (plasticity). Rolled products with plasticity δ_{max}≥7.5% (high category of deformability) are considered the most reliable and are used for construction in regions with increased seismic activity. Achieving a high category of deformability is ensured by the chemical composition of steel and the technology for the production of rebar.

Keywords: Earthquake; Deformability; Carbonitride; Cold resistance

High Quality Rebar Deformability

Obtaining steel products for construction purposes of a higher strength class without alloying steel with expensive substitution elements (Cr, Ni, Mo, etc.) is achieved through the implementation of the mechanisms of dispersion and grain boundary strengthening. These mechanisms are realized by the formation of excess carbonitride phases during the alloying of steel with elements that have an increased affinity for carbon and nitrogen. In order to obtain increased indicators of mechanical properties and performance characteristics of steel of the ferrite-pearlite class, they are additionally alloyed with strong sodium o-and carbonitride-forming elements, such as vanadium, titanium, niobium, etc. ferrite grain refinement and

*This article is the author's private response to the consequences of a specific event of world significance-an earthquake in Turkey and Syria that occurred in February 2023 carbonitride formation. In this case, the dispersion and amount of this excess phase is determined not so much by the level of concentrations and the ratio of phase-forming elements, but by the temperature regimes of rolling and thermomechanical processing. An example of obtaining products with a high level of strength and deformability is the production of reinforcing bars of the An600S class from steel grade 20G2SFBA [3]. And endurance tests, as well as low-cycle fatigue, proved the validity [3] application of this product under seismic loads (can be used in structures subject to alternating loads). Another way to form carbonitrides in steel is its additional alloying with nitrogen in the amount of 0.010-0.025%. In the case of carbon steel microalloying with titanium and aluminum, the former determines the level of nitrogen solubility in the liquid metal and the formation of carbonitride inclusions in the melt, and also acts as a second-class inoculator and acts as a regulator of the size of the primary cast grain. Aluminum, whose nitrides are formed in solid metal, are responsible for the grain structure of steel during thermomechanical processing of rebar. Thus, an increase in the level of strength and plastic properties of finished products can be achieved by introducing the technology of carbon nitride hardening based on steel alloying with nitrogen, titanium, and aluminum.

Carbonitrides can be formed in the production of hot-rolled products from 20ATYu steel. The first type of Ti (C,N) has rather large dimensions (1-12μm) and is formed even in liquid steel. The second type of titanium carbonitrides has dimensions (10-200nm) and is most likely precipitated during solidification and cooling of steel in the solid state. There is also an opinion [4] that, for the most efficient use of complex microalloying of low-alloy steels with nitrogen, titanium and aluminum, it is necessary to create conditions for obtaining as many small titanium carbonitrides as possible and to provide thermodynamic and kinetic possibilities for the formation of aluminum nitrides in sufficient volume. Microalloying with titanium within optimal limits significantly increases the strength and toughness of 20GATYU steel [5]. In this case, the maximum increase in strength (50-80MPa) is observed with a titanium content of 0.020-0.025%, i.e., with the highest total amount of titanium carbonitrides, as well as with a high proportion of fine particles (≥45%). At the same time, the increase in impact strength (by a factor of 1.5-2.0) is only affected by an increase in the proportion of Ti (C,N) fine particles. Apparently, the established patterns could have a beneficial effect on the level of consumer properties (strength and deformability) of reinforcing bars [6-8]. The results presented above on the mechanical properties of steel products with carbonitride hardening indicate that this method is an effective way to increase the strength and deformation properties of metal products. Based on this, the consumption of rebar made of steels with carbonitride hardening in modern construction should increase. At the same time, comparing the costs of steel hardening, it should be recognized that purposeful alloying of steel with vanadium, niobium and molybdenum is a more expensive way to improve the consumer properties of finished products. This method in the conditions of fierce competition in the market will not be accepted by many manufacturers of these products. An alternative way would be to recognize hardening by additional introduction of nitrogen, titanium and aluminum into the steel. The effectiveness of the latter has also been proven for other types of metal products, where the total costs did not exceed 2-5% of the cost of the finished product [5]. Therefore, alloying of steel with the system" nitrogen-titanium-aluminum" will actually ensure the production of reinforcing bars of strength class 500MPa from manganese-silicon steel grade 20GS with a high level of de-formability characteristics (δ_{max}≥7.5%) for the construction of seismically active regions.

Aspects of the Use of Rebar and Control of its Properties

The modern use of metal products in the construction of civil and industrial buildings, as well as special facilities (nuclear power plants, sea berths, high-rise buildings, etc.) is focused on the use of reinforcing bars with a wide range of high consumer properties-indicators of deformability, endurance, weldability, corrosion resistance, cold resistance, fire resistance and fire safety. This is especially true when it comes to construction in regions with difficult climatic and seismic conditions. In the context of the topic under discussion, let us dwell on the use of rebar for construction in seismically active regions. It is known that the European standard for the design of earthquake-resistant structures [9] prohibits the use of reinforcing bars as the main (working) one, which has a characteristic of full relative elongation at maximum load (δ max) of less than 2.5% with a magnitude of 7 points, less than 5%-8 points, less than 7%-9 points. Similar requirements are present in the standards of other states, for example, Turkey and China. In connection with the requirements of these regulatory documents for the design of earthquake-resistant structures and the relevance of this topic in general, it is necessary in the near future to increase control over the implementation of design standards, as well as change the approach to monitoring the strength and deformability characteristics of reinforcing bars for construction in regions with seismic activity over 7 points. To do this, it is necessary to introduce a new system for monitoring the mechanical properties of the used reinforcing bars [10,11] with an increase in the number of samples subjected to tensile tests (for example, according to the method of [11]), as well as to carry out 100% control of the properties of the reinforcing bars used, by analogy with automotive fasteners, using available methods (for example, by controlling the coercive force). The proposed method [11] makes it possible to test rods and identify reinforcing bars for compliance with the requirements of regulatory documents on the simplest testing machines without recording tensile diagrams and using special sensors.

Conclusion

a. The production of reinforcing bars of strength class 500-600MPa from steel with carbonitride hardening significantly improves the consumer properties of finished products, such as strength, deformability, fatigue strength (endurance) and other characteristics.

b. The use of reinforcing bars of strength class 500-600MPa from steel with carbonitride hardening provides an increase in the re-liability of reinforced concrete structures and structures, especially during construction in regions with increased seismic activity.

c. It seems more promising, rational and economically justified to carry out carbonitride hardening of reinforcing bars of strength class 500-600MPa by modifying steel with the "nitrogen-titanium-aluminum" system.

d. To ensure the mass use of rebar for construction in seismically active regions, it is necessary to improve the regulatory framework for its production and use, as well as the introduction of new methods for controlling mechanical properties.

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