Applied Mechanics and Materials Vols. 204-208 (2012) pp 3052-3056
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doi:10.4028/www.scientific.net/AMM.204-208.3052

ANALYSIS OF PROPERTIES OF REINFORCING STEEL BARS: CASE STUDY OFCOLLAPSED BUILDING IN LAGOS, NIGERIA

Odusote Jamiu Kolawole[1, a] Adeleke Adekunle Akanni[2, b]

[1, 2]Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria.

[a]jamiukolawole@gmail.com/abduljamiuk@yahoo.com, [b]adeleke.kunle@ymail.com

Keywords: Reinforcing steel bars, Collapse building, Residual elements, Microstructure, Hardness value

Abstract

The chemical compositions and the microstructures of reinforcing steel bars obtained from three different collapsed building sites were studied. Optical emission spectrometer was used to carry out the chemical analysis, while the microstructure was examined using an optical microscopy. The carbon contents of the steel bars were found to be higher than BS4449 and ASTM706 standards, but they are in close range with the Nst-65-Mn standard. The manganese contents of the steel bars are lower, while the sulphur and phosphorus contents are quite higher than the BS4449, ASTM706 and Nst-65-Mn standards. The hardness values of the investigated bars are higher than recommended BS4449 standard but lower than Nst-65-Mn standard. Brittle globules of Fe_3P and FeS were observed within the structure possibly due to higher contents of deleterious sulphur and phosphorus. The results suggest that the investigated reinforcing bars are brittle and thus contributing significantly to the collapse of the building structures.

Introduction

Housing has formed a cogent part of human need as next to air, water and food [1]. It has also become an important aspect of socio-economic development of human being [2]. As the population of the country grows in the recent time, so also is the government, corporate organisations and individual housing demand for residential, industrial and other purposes are increasing [3]. For all these demands, safeguiding of lives and properties is very pertinent, and thus building collapses during and after construction must be avoided [2]. The collapse of building either in part or completely results not only in wasted efforts or investment but also in loss of lives [4].

As a result of building collapses, Olateju [5] reported that a total of 174 deaths were recorded in Nigeria between 1971 and 1990. Chinwokwu [6] also reported about 42 cases that resulted in 126 deaths between 1980-1999. Similar result was obtained by Folagbade [7], who also reported 42 cases under the same time frame. Fagbenle and Olawumi [8] enumerated 61 reported cases of collapse between 1974 and 2010, which resulted in 303 lives been lost apart from unreported cases. More than 14 person were reported died on 12th August 2010, when a building collapse in Nigeria Federal capital, Abuja as reported by cable network news [9]. Punch newspaper [10] also reported death of at least 3 people in September, 2010 as a result of building collapse in Lagos. Between 2005-2010, not less than 264 deaths were recorded from about 25 cases of building collapse as reported by Ede [11]. Cases of building collapses still remain numerous even at the recent time. National Building and Road Research Institute (NBRRI) [12] reported that building collapses are more common in cities of Lagos, Enugu, Abuja and Port Harcourt, with about 60% of the collapses occured in Lagos. In early part of year 2011, a 6-storey building and a 5-storey Hotel building collapsed in Lagos, Nigeria. Under the same time frame, 3 building collapse in Enugu, while a 4-storey hospital building and 2-storey bank building collapsed in Abuja, Nigeria as reported by NBBRI [12]. These and many other unreported cases resulted in lost of many lives and properties worth millions of Naira [8, 11, 12]. Several factors have been itemized to be responsible for this incessant collapse, some of which are structural failures, use of poor workmanship, incompetent supervisors, unauthorized conversion of boungalow to storey buildings, carelesssness, rainstorm, faulty design/implementation, use of substandard materials, excessive loading, disregard for building resolution, improper drainage, contravening the given approval, among other factors [8, 12]. Despite these findings, cases of building collapse still persist. In this year alone, several cases of building collapse have been reported. These cases include a building collapse in Abuja on 29th January 2012 where 2 people were reportedly dead while several others were trapped [10]. Another buillding collapsed in Awka, Anambra state, Nigeria on 2nd March, 2012 [10], while a 5-storey building also collapsed in Lagos on 5th March of this same year [10]. In a previous study, reinforcing steel bars from most of the Nigerian steel industries have been found to be suitable for construction work due to their higher mechanical properties than the standards, Alabi and Onyeyi [13]. However, since the incident of building collapses in Nigeria is assuming an alarming rate, it has become overwhelming important to conduct further investigation into the suitability of the reinforcing steel bars taken from the collapse building sites. Thus, the objective of the present work is to examine the chemical composition, microstructure and hardness value of the reinforcing steel bars from some of the collapsed building sites. This will assist in determining the contribution of this essential building material to building failure/collapse by comparing our results with several standards.

Experimental procedure

Samples of reinforcing steel bars were obtained from three collapsed building site in Lagos. The areas are Ewutuntun (EC), Ilesanmi (IC) and Sango (SC) in Lagos. The chemical compositions of the samples were obtained using optical emission spectrometer. An optical microscope was used for the microstructure observation. Brinnel hardness testing machine was used for the hardness test.

Results

The chemical compositions of the samples are presented in Table 1. Figure 1 shows the phosphorus, sulphur, manganese and carbon content of the samples investigated comparing them with BS4449, ASTM706 and Nst-65-Mn standards. The results obtained from Brinnel hardness test are 21.19HRC for EC, 20.22HRC for IC and 19.63HRC for SC. These values are compared with BS4449 and Nst-65-Mn standards and presented in Figure 2. Figure 3 is the optical micrographs of the samples in x400 showing the ferrite and pearlite.

Table 1: Result of the chemical analysis of the samples.

Element%	EC	IC	SC	Element%	EC	IC	SC
C	0.339	0.3110	0.345	Cu	0.283	0.284	0.282
Si	0.231	0.223	0.206	W	0.012	0.012	0.011
S	0.080	0.086	0.079	Ti	0.002	0.002	0.002
P	0.069	0.079	0.068	Sn	0.016	0.016	0.015
Mn	0.983	0.991	0.806	Co	0.011	0.011	0.011
Ni	0.106	0.107	0.110	Al	0.006	0.003	0.004
Cr	0.223	0.223	0.225	Nb	0.001	0.001	0.001
Mo	0.030	0.030	0.031	Fe	97.602	97.615	97.618
V	0.006	0.006	0.006	-	-	-	-

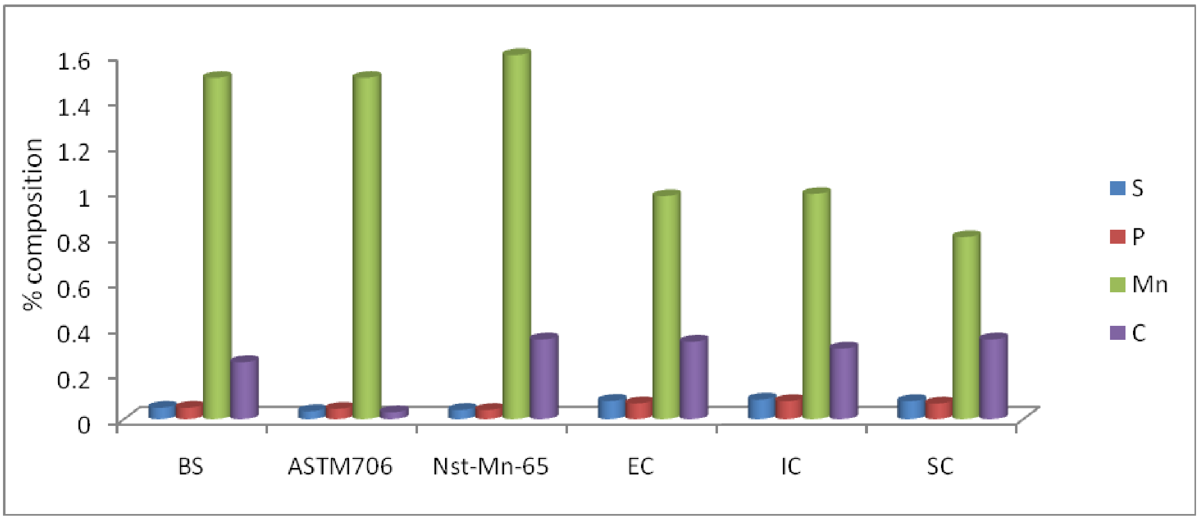

Figure 1: % composition of sulphur, phosphorus, manganese and carbon contents of the samples compare with standards.

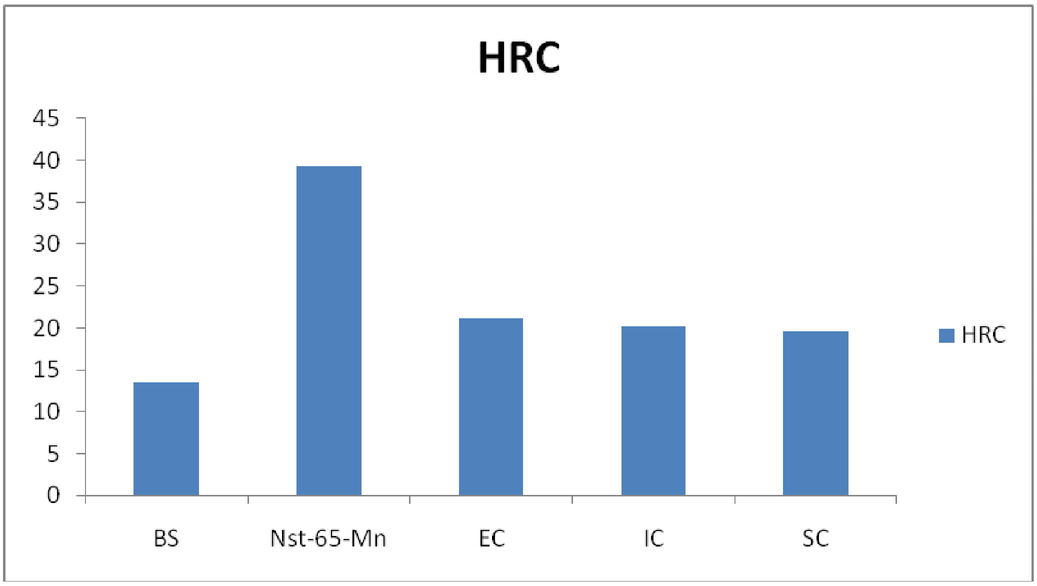

Figure 2: Hardness values of the samples compared with standards.

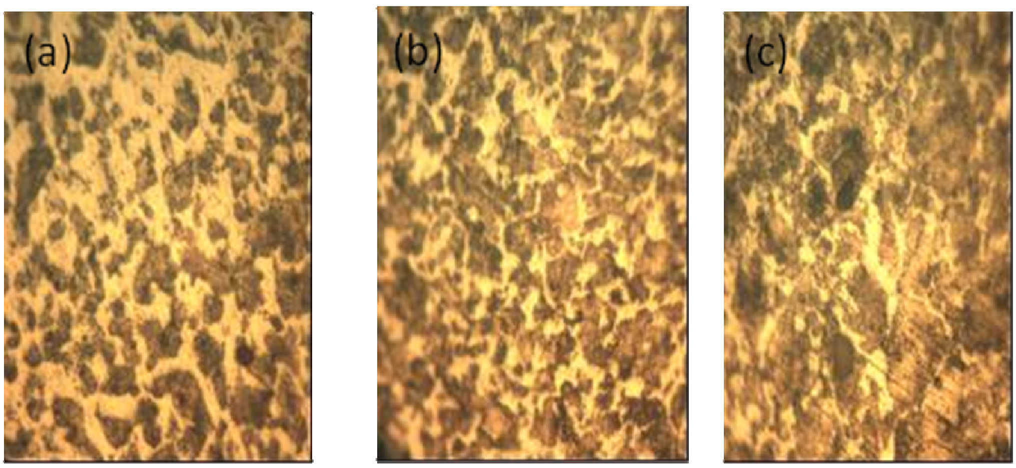

Figure 3: Optical microscopy of (a) EC, (b) IC, and (c) SC in x400 magnification etched using nital (2% nitrate and 98% alcohol).

Discussion

The carbon contents of the investigated reinforcing steel bars from the collapsed building sites surpassed the BS4449 [14] and ASTM706 [15] maximum limits of 0.25 and 0.30 carbon requirement for such steel bars but they are in close range with the Nst-65- Mn standards [16]. Thus, the bars are harder than the recommended standard by BS4449 but not as hard as that of Nst-65-Mn standard even though their carbon content is in close range. This may be due to combined effects of other constituent elements of the bar. Alabi and Onyeji [13] also reported the presence of higher carbon contents compared with the standards in the reinforcing steel bars from most of the Nigerian steel industries. The samples from the sites are harder probably due to their higher carbon contents, which is more compared with BS4449 standards. Carbon is the most important constituent element of steel, its stability affects the tendency to increase hardness and strength of steel [17]. Hardness of plain carbon steel increases with increasing carbon content. As the carbon content increases, the amount of ferrite present decreases while the amount of pearlite increases. When the carbon content of the steel reached 0.8 percent, it will entirely compose of pearlite [18].

The phosphorus and sulphur impurities in the investigated reinforcing steel bars exceeded the standards, leading to increased hardness and strength, and decreased ductility, and thus making the bars brittle. The brittleness may be due to the formation of FeS and Fe_3P, which are brittle compound. Sanmbo et al [19] also identified that the mild steel produced in Nigeria has low strength as a result of residual elements such as S and P in the scraps used for production. The ductility characteristic of reinforcing steel bar milled from scraps were worked upon by Charles et al [20], and observed that the strength of the bars is too high with very little elongation leading to limited ductility. According to Moore [21], increase in the residual elements above the required standards is deleterious to the steel. The presence of large ferrite areas covered with the excess sulphur and phosphorus within the structures has shown in Figures 3 also indicated that the bars are brittle.

Conclusion

The results of the analysis show that the reinforcing steel bars used in the collapsed building sites are brittle. Their hardness value is far below the Nst-65-Mn standard and such may not be well fitted for structural application of this nature. High level of sulphur and phosphorus impurities as well as presence of deleterious FeS and Fe_3P in the microstructure may be responsible for the brittleness of the bars. The necessary ductility needed has been tampered with as a result of the presence of these compounds. Thus, the reinforcing steel bars may have significantly contributed to the collapse of the buildings due to their lack of ductility and brittleness.

Acknowledgements

We hereby acknowledged the numerous support of Mr Alo (Department of Material Science and Engineering, Obafemi Awolowo University Ife, Ife, Nigeria) during materials testing. The support of the University of Ilorin, Ilorin, Nigeria is also warmly appreciated.

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