Environmental Impact on Engineering Materials: Galvanized Steel.

O.K. Ukoba, B.Eng.[1]; P.K. Oke, Ph.D.[2]; A. Adenuga, B.Eng.[2]; M.C. Ibegbulam, B.Eng.[1*]

[1]Engineering Materials Development Institute, Akure, Nigeria.
[2]Federal University of Technology, Akure, Nigeria.

E-mail: colbeibe@gmail.com*

ABSTRACT

The problem of failed structures and machines, most especially in developing countries like Nigeria, has, and is still claiming lives in large number on a daily basis. This research aims to investigate if the environment of the material has any effect, and what is this effect, on the by-product.

A galvanized sheet of 900 mm by 600 mm was cut into three samples of equal shape and size. Each sample was subjected to various environmental condition (open air, A/C, and room temperature environments) and tensile and hardness tests were performed on them. From the calculations, the averages of corrosion rates for each of the samples are 58.90, 58.94, and 58.71. The result was shocking. The results reveal that the environment used in storing the engineering materials plays a significant role in corrosion and the result is that materials exposed to an open environment are prone to more environmental defects than those kept in a confined area where the necessity of inventory was put into consideration. The environmental agents attack the microstructure and chemical composition of the materials, thereby altering the properties for which the selection of the materials is based upon.

(Keywords: environment, environmental conditions, engineering materials, galvanized steel, corrosion)

INTRODUCTION

The incessant collapse of buildings, failure of structures like bridges, and even shortage or irregular water supplies by the water works is becoming a source of concern to the people of developing nations, especially Nigerians. Adejuyigbe (2001) looked into the frequent burst of crude oil pipelines in Nigeria which have resulted in the deaths of so many in Nigeria. His research investigated the causes of pipeline burst or oil spill incidents from 1990 to 1998, using the crude oil pipeline in one of the foremost petroleum development companies based in Nigeria. The research findings reveal that the major cause of pipeline burst is corrosion. Other factors are the results of sabotage, mechanical failure, production operations, and engineering activities.

In this research paper, we investigated galvanized steel behavior in various environments, namely:

i. Air conditioned environment
ii. Room temperature environment
iii. Air

In Nigeria for instance, engineering materials are purchased by the materials sellers and majority of them are left in the open air before eventually being sold to the industries that use them. These industries in turn expose the materials to the above mentioned environments.

MATERIALS AND METHODS

Methodology

The sheet metal used in this study was cut into specific size and exposed to the various environments. Tests were carried out periodically to assess the state of the test materials.

Materials

A steel sheet 900 mm by 600 mm was cut into three samples of equal shape and size and polished with emery papers and diamond paste.

Equipment

i. Grinding machine,
ii. Instron Universal Tester,
iii. Hack saw,
iv. Rockwell hardness tester,
v. Hardness tester,
vi. Polishing machine,
vii. Microscope and camera.

Experiment Technology

To investigate the environmental impact on the mechanical properties of steel sheet, three samples of steel sheet were kept in three different environmental conditions. The first one was kept in an open air environment to be acted upon by rain and sunshine; the second one was kept in the workshop; and the third one was also kept in a controlled environment with controlled temperature (air condition). At three week intervals, tests samples were cut from each of the sample and various tests were carried out including:

i. Micro structural test
ii. Hardness and stress analysis
iii. Tensile test.

The result obtained from these tests/analyses was compared with the physical properties of the samples before exposure to the varying environmental conditions.

Micro Structural Tests

This consists of micrographic studies of structure characteristics of the samples to determine the grain size and shape distribution of various phase and inclusion which have a great effect on the mechanical properties of metals.

Sample Preparation: The samples for microstructure examination were prepared by cutting 10 mm by 10 mm by 2 mm sections from each sample using hack saw and smooth file.

Mounting: The sections cut from the samples were too small both in breath, length, and thickness to handle. Therefore they were mounted on Bakelite for easy operations.

Grinding: The samples were ground, one after the other, firstly by using a finishing belt, followed by a series of successive grinding on a grinding machine using progressively finer grades of emery papers (220, 240, 320, 400, and lastly 600 - from coarse to fine), respectively. The samples were rough ground on the grinding machine and pressed down lightly on the rotation wheel of the grinder covered with emery papers to remove the hack saw and vice marks. Intermediate and fine grindings were then carried out on the emery papers. Grindings continues until surface was flat and free of nicks, scratches, and burrs.

Polishing: The samples were then taken to the polishing machine which is made up of horizontally rotated cloth coated disk. The sample was pressed down on the rotating disk, after some time distilled water was applied to reduce friction and prevent heat that might have an effect on the structure of the samples, and then powdered diamond paste was applied to aid the polishing produce a mirror- like finish.

Etching: Before the samples were analyzed microscopically, the surfaces of the samples were thoroughly cleaned to eliminate stains during polishing. The samples were held with a pair of tongs and dipped into boiling ethanol for about a minute to remove any grease or dirt on its surface. It was removed from the ethanol and cooled under the tap water.

After thorough cleaning, the samples were etched using natal enchant, 2% HNO_3 and 98% alcohol. It was agitated for several minutes and cleaned under water to remove the etchant. The micrographs of each sample were then taken, developed, and printed separately. The micrographs were taken using the software driven metallurgical microscope available at the Engineering Materials Development Institute (EMDI), Akure, Nigeria.

Tensile Tests

Sample Preparation: A sample 220mm by 40mm by 2mm was marked and cut from each plate sample with the aid of a guillotine machine. This material was then mounted on the table vice and cut into the required size with the aid of hack saw and smooth file.

RESULTS AND DISCUSSION

Micrographs of Control Sample

100X

Figure 1: Micrograph of Control Sample.

OFFICE (100X)

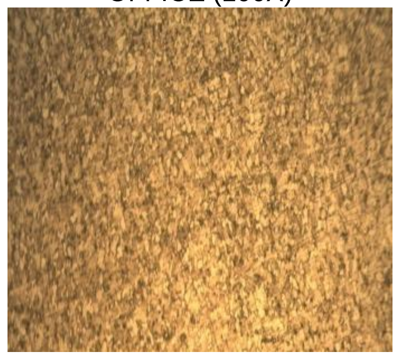
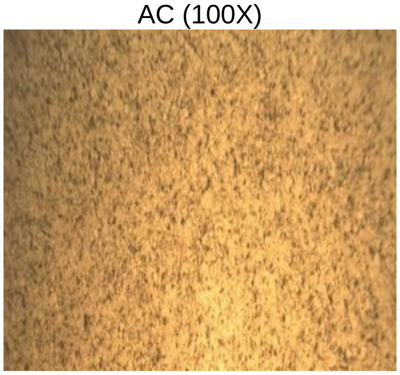


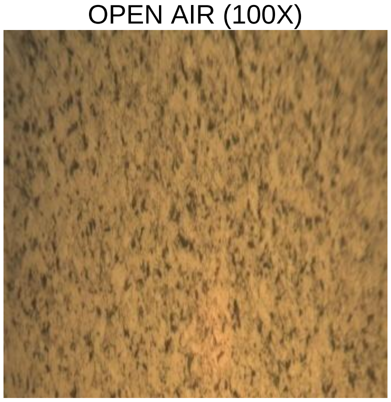
Figure 2: Micrographs of 1st Test.

MICROGRAPHS OF 1st TESTS

AC (100X)

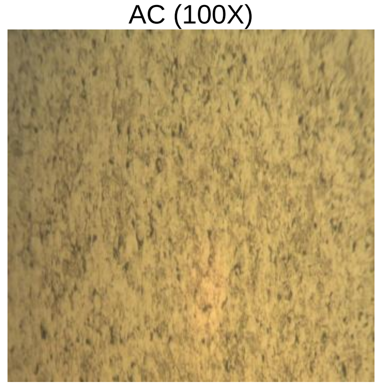


OPEN AIR (100X)

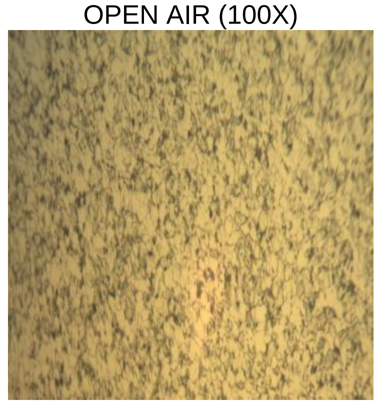


2ND TESTS MICROGRAPH

AC (100X)



OPEN AIR (100X)



OFFICE (100X)

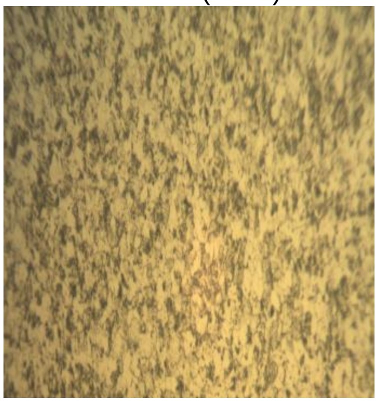


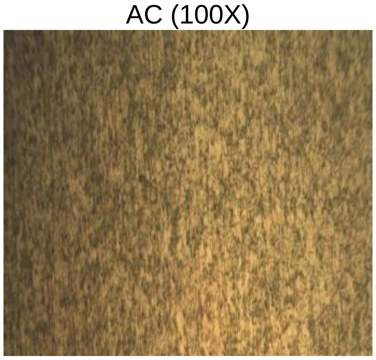
Figure 3: Micrographs of 2nd Tests.

OFFICE (100X)

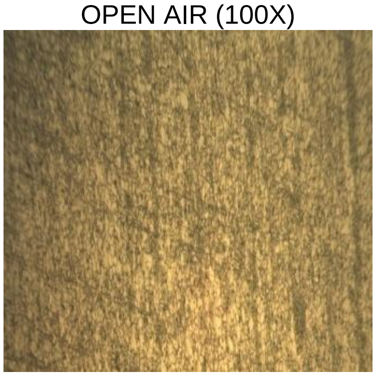
Figure 4: Micrographs of 3rd Tests.

2rd TESTS MICROGRAPH

AC (100X)



OPEN AIR (100X)



TENSILE TESTS

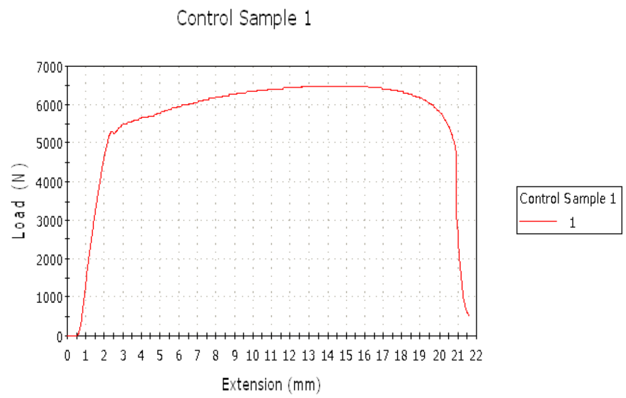


Figure 5: Tensile of Control Sample.

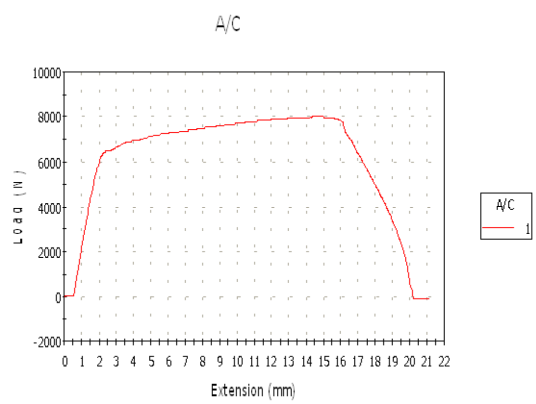


Figure 6: Tensile Graph of 1st Test AC.

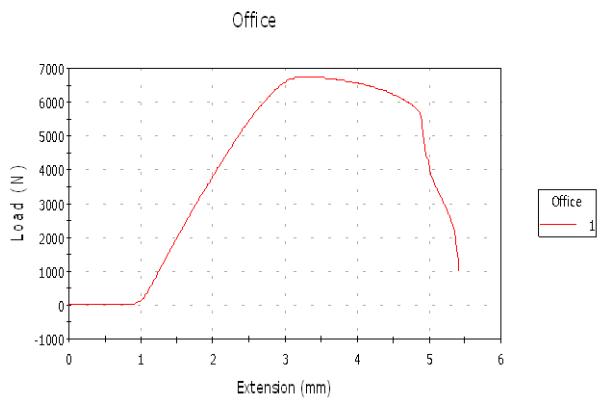


Figure 7: Tensile Graph of 1st Test Office.

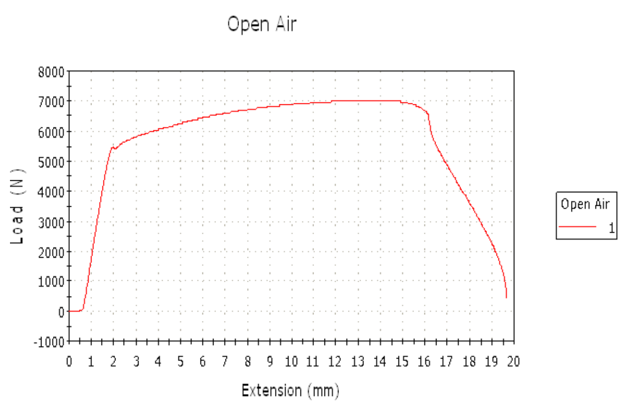


Figure 8: Tensile Graph of 1st Tests Open Air.

2nd PRATICAL: Tensile Galvanized Steel Sample

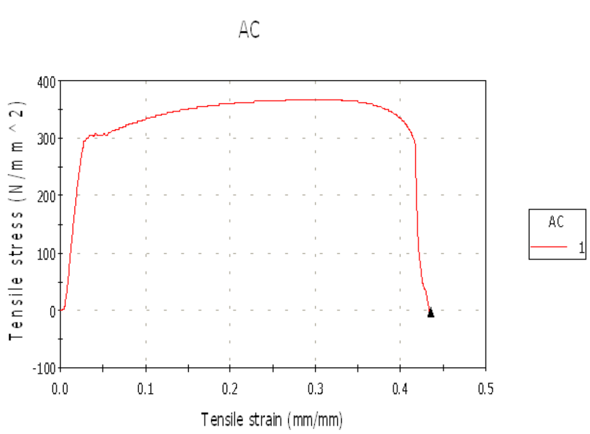


Figure 9: Tensile Graph of 2nd Tests AC.

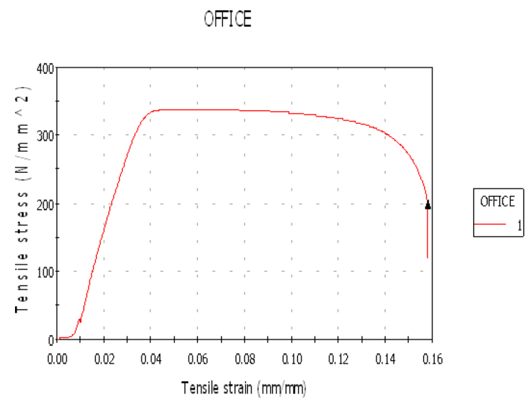


Figure 10: Tensile Graph of 2nd Test Office.

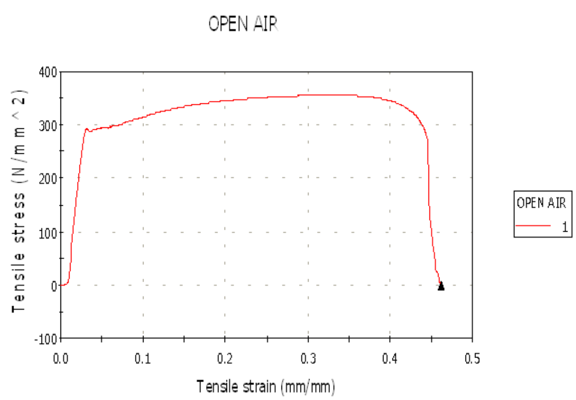


Figure 11: Tensile Graph of 2nd Tests Open Air.

3rd PRATICAL: Tensile Galvanized Steel Sample

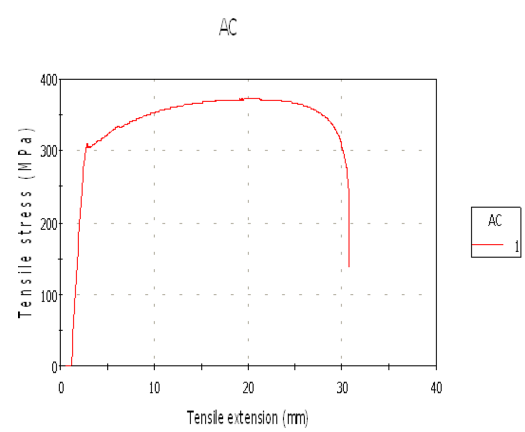


Figure 12: Tensile Graph of 3rd Tests AC.

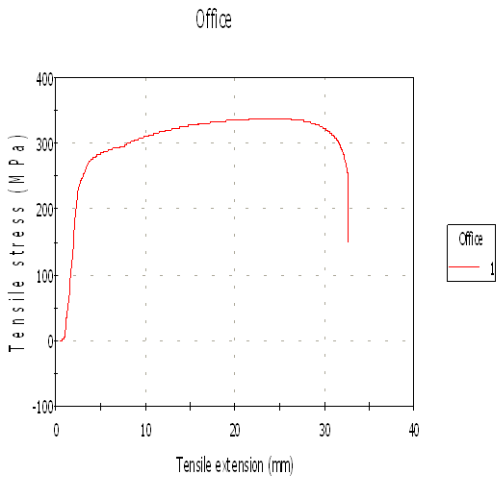


Figure 13: Tensile Graph of 3rd Tests Office.

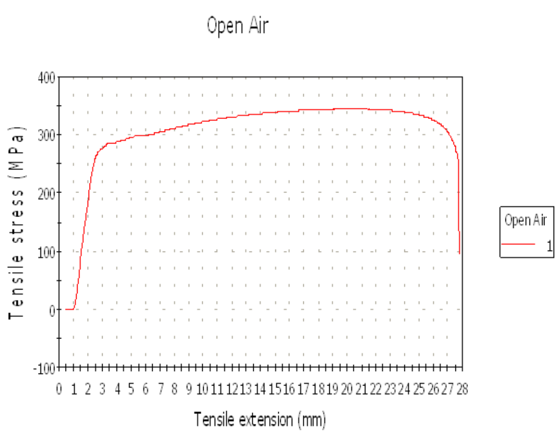


Figure 14: Tensile Graph of 3rd Tests Open Air.

HARDNESS TESTS

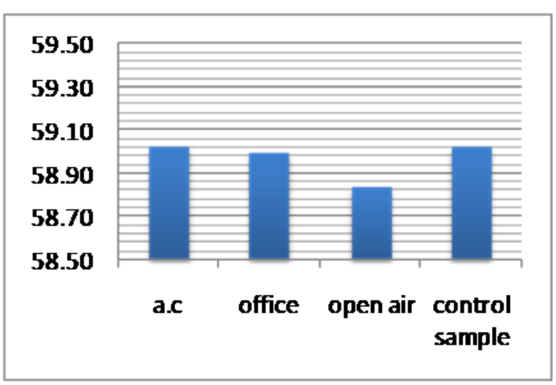


Figure 15: 1st Hardness Test.

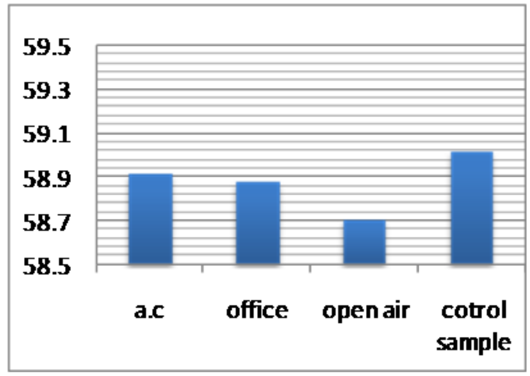


Figure 16: 2rd Hardness Test.

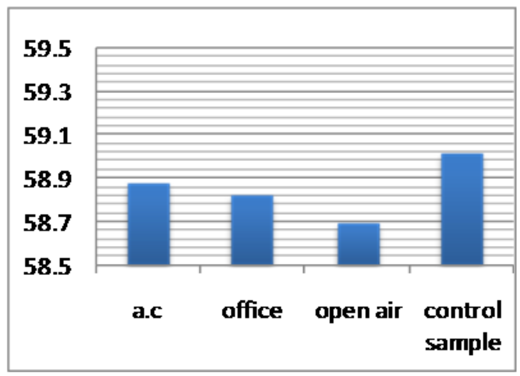


Figure 17: 3rd Hardness Test.

DISCUSSION

Based on visual observations, there were no distinctive differences in the corrosion rate of the samples [air conditioning, office, open air control; sample], in terms of the micro structural examinations. Steel coated with zinc has higher corrosion resistance than other kinds of steel.

Zinc itself offers good resistance to corrosion to a certain extent in proportion to duration of exposure to corrosive or environmental defects. The corrosion effect was felt at the surface of the metal but has to be grinded and polished before the tests. Therefore it takes a longer time for the corrosive agent to get into the steel itself. Due to grinding and polishing, the corroded surface has been cleaned during micro structural examination which enables the samples to have similar structural defects.

The micrographs illustrate the structural components which are pearlite [darkish and hard] and ferrite [whitish and soft.]. Before exposure, [control sample], it was observed that the structure has more Pearlite than the ferrite. As the corrosion increases or corrosion rate, the ferrite begins to grow although in small quantities which has little effect on the materials. That means the corrosion rate is proportional to the duration of exposure and environment which is being exposed. The experiment was carried out four times at three weeks intervals on each sample at magnification of 100X magnification.

Tensile Test

The table and the graphs illustrate various tests carried out on each samples at three weeks intervals. As a result of corrosion there are variations in the mechanical properties of the materials in terms of the tensile stress, strain, load at yield load at brake, area, length elongation, etc. The graphs and tables throughout show some small variation in properties along with their values.

Hardness

There were small defects in structures observed during the micro structural examination. The hardness tests were done with the aid of the Rockwell hardness tester with 60kg ball indentation and were tabulated on a bar chart in the previous page. The environmental defects were visible although with little variations because the samples were not ground and polished. The tests were carried out five times on each sample at three weeks intervals and the average was calculated to determine the reduction in the hardness value of the metals. It was observed that the air conditioning sample maintained the best hardness value compare with the control sample piece, followed by the office sample, and lastly the sample in the open air.

The values obtained during the five time trial were calculated below including the average.

Table 1: First Test.

NUMBER	OFFICE	AIR CONDITION	OPEN AIR
1	58.0	59.2	59.0
2	59.0	59.5	58.8
3	59.4	58.6	58.6
4	59.4	59.5	58.8
5	52.2	58.3	59.2
TOTAL	295	295.1	294.4
AVERAGE	59.00	59.02	58.84

Table 2: Second Test.

NUMBER	OFFICE	AIR CONDITION	OPEN AIR
1	57.8	58.5	58.5
2	58.8	58.8	58.2
3	59.4	59.3	59.0
4	59.0	59.5	59.1
5	59.2	59.0	58.3
TOTAL	294.4	294.6	293.5
AVERAGE	58.88	58.92	58.7

Table 3: Third Test.

NUMBER	OFFICE	AIR CONDITION	OPEN AIR
1	59.0	59.1	58.6
2	59.5	58.9	58.6
3	58.2	58.7	58.7
4	58.9	59.0	58.3
5	59.0	58.7	58.8
TOTAL	294.1	294.4	293
AVERAGE	58.82	58.88	58.6

From the calculations above, the average corrosion rates for each samples are 58.90, 58.94, and 58.71.

TESTS	OFFICE	AIR CONDITION	OPEN AIR
First tests	59.00	59.02	58.84
Second tests	58.88	58.92	58.7
Third test	58.82	58.88	58.6
Total	176	176.82	176.14
AVERAGE	58.90	58.94	58.71

CONCLUSION

Corrosion brings about deterioration in the mechanical properties of engineering materials (metals) when exposed to corrosive environment (atmosphere, acids, aqueous solution, molten salts, organic solvents, etc.). Corrosion rates differ among materials because of varied properties, components, and environments (depends on humidity, temperature, flow rate, etc.). Engineering materials application in more polluted, industrialize and marine areas are prone to more environmental defects than those at less polluted, industrialize and marine areas.

This research shows the reason why galvanized steel is the most used in engineering applications (design, construction, and fabrication) due to its ability to resist corrosion for a longer period. It also indicates that there should be proper inventory control on materials storage. Materials exposed to an open environment are prone to more environmental defects than those kept in a confined area where the necessity of inventory was put into consideration. The environmental agents attack the microstructure and chemical composition of the materials. Thereby altering the properties for which the selection of the materials is based upon.

RECOMMENDATION

In material selection for engineering applications, the design engineer should be careful to select the appropriate materials keeping in mind the environment in which the design is to be subjected to and its purpose prior to its use in any standard applications. Proper storage should be selected to avoid breakdown and premature failure as a result of stress and corrosion fatigue, resulting in formation of cracks and subsequent failure of the materials. In addition engineering materials should be purchase in sales outlets that understand the importance of inventory control in materials storage.

REFERENCES

1. Engineering Materials Development Institute (EMDI). Ondo Road, Akure, Ondo State, Nigeria.

2. Guy, A.G. 1987. *Essentials of Materials Science.* McGraw – Hill: New York, NY. 214- 215.

3. Higgins, R.A. 1993. *Engineering Metallurgy. 6th Edition.* Butterworth-Heinemann, New York, NY.

4. Schackel, J. 2000. *Introduction to Materials for Engineers*. Macmillan: London, UK. 291-293.

5. Khanna, O.P. 1996. *A Textbook of Foundry Technology for Engineering Students*. Dhanpat RIA Publication Ltd.: New Delhi, India.

6. Stoloff, N.S. and Sikka, V.K. 2006. *Physical Metallurgical and Processing Of Intermetallic Compounds*. Springer: London, UK.

7. Prabhudey, K.H. 2006. *Hand Book of Heat Treatment of Steel*. Tata Mc Graw–Hill: New Delhi, India.

8. Scutty, J.C. 1999. *Fundamental of Corrosion. 3rd Edition*. Pregagon Press: New York, NY. 26-28.

9. Scrivastaua and Scrinivasem. 1987. Science of Engineering Materials. Wiley Eastern Ltd.: New Delhi, India. 166.

10. Callister, W.D., Jr. 2000. *An Introduction to Material Science and Engineering*. Wiley: New York, NY.

11. Adejuyigbe, S.B. 2010. “Manufacturing and Computer Aided Engineering: A Panacea for Wealth Creation”. University of Agriculture, Abeokuta, Nigeria. Inaugural Lecture series No. 27: 55

ABOUT THE AUTHORS

Dr. P.K. Oke, is a Professor in the Department of Mechanical Engineering, Federal University of Technology, Akure. He holds a Ph.D. degree in Mechanical Engineering and currently serves as the sub- Dean of School of Engineering of same.

K.O. Ukoba, is a Design and Simulation Engineer in the Manufacturing Department, Engineering Materials Development Institute, Akure, Nigeria. He holds a B.Eng. degree in Mechanical Engineering and currently doing his M.Eng. in Mechanical Engineering. His research interests are in the areas of design/simulation, materials (testing and synthesis), corrosion, and ergonomics.

M.C. Ibegbulam, holds a bachelor degree in Materials and Metallurgical Engineering and is currently a research officer in Engineering Materials Development Institute, Akure, Ondo State (EMDI). His research interests are in the

areas of corrosion and material science/engineering.

A. Adenuga, holds a bachelor degree in Mechanical Engineering. His research interests are in the areas of Corrosion and Material Science/Engineering.

SUGGESTED CITATION

Ukoba, O.K., P.K. Oke, A. Adenuga, and M.C. Ibegbulam. 2011. "Environmental Impact on Engineering Materials: Galvanized Steel". *Pacific Journal of Science and Technology*. 12(1):62-70.

Pacific Journal of Science and Technology