Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-, Vol.15

January 20, 2015

Effect of Bending and Straightening to the Strength of Reinforcement Steel Bar

Kana Sabatul Ikhwan,[a,*] and M. Dalil,[a]

[a)]*Mechanical Engineering, Universitas Riau, Indonesia*

*Corresponding author: ikhwan36@yandex.com

Paper History

Received: 1-December-2014
Received in revised form: 15-December-2014
Accepted: 15-January-2015

ABSTRACT

One of reinforcement bar treatment during delivery transportation is to bend up or buckle in the middle of the bar. This treatment will undermine the strength of the reinforcement bar on buckle region due to its mechanical properties have been changed and no longer within specification. An important point of this study is to knowing the rate of change of mechanical properties, especially strength. Concrete reinforcing steels are bent with nine variations of the bending angle starting from the angle (α) of 20o , 40o , 60o , 80o , 100o , 120o , 140o , 160o , and 180o. The data obtained indicated that the yield strength and ultimate tensile strength increases and decreasing the ductility. The increasing percentage of the yield strength is 14% and the tensile strength is 7%. The maximum decreased elongation is 13.42% (α = 180º) from 24.67% (α = 0º) and the reduction of area is decreasing 1.93 %.

KEY WORDS: *Bending; Steel Structures; Mechanical Properties.*

NOMENCLATURE

A□	Initial Area (mm²)
Δ*L*	Length Increasing (mm)
D	Specimen Diameter (mm)
E	Modulus of Elasticity (GPa)
EL	Elongation ductility (%)
ε	Strain
F	Tensile Force (N)
σ	Normal Stress (N/mm²)
G	Gauge Length (mm)

1.0 INTRODUCTION

Riau Province continues to accelerate infrastructure development is a key to spurring economic development in the communities in Lancang Kuning Earth. Construction of the physical facilities requires structural steel reinforcement as one of the main ingredients for reinforcing the strength of the concrete building. Concrete reinforcing steel structure production experience both the bending process for a particular purpose or other. One example is the bending of simplifying the transport of manufacturers in Jakarta or Medan to get to Pekanbaru Riau province or territory area through land transportation vehicles with a limited size (Shown in figure. 1).

Figure 1: Concrete reinforcing steel transportation (location: Pekanbaru)

There is also a reality in the field is not willful bending the current loading and unloading process and the reinforcing steel travel until it gets to the consumer. Bending process can affect the mechanical properties. In stretch bending, it is shown that the local deformations of the cross-section during bending are primarily controlled by the geometry and tensile force level. The main parameters influencing the spring back during unloading are the strain hardening properties of the material, and the tensile force [9]. This study aims to determine the tensile strength of concrete reinforcing steel before experiencing a particular treatment (standard production results from the manufacturer). Knowing the tensile strength of concrete reinforcing steel after being subjected to bending and straightened out again. The bending process is done with nine variations of angle alpha. The selected angle is (α) 20o, 40o, 60o, 80o, 100o, 120o, 140o, 160o, 180o, then straightened back and pull testing to obtain the mechanical properties. Bending process using a universal testing machine and the alignment process using a power screw where it works to reverse direction when bending force vector. The alignment process is not exactly perfect and it was included in the sample treatment. The benefits of this research to inform the general public is that the concrete reinforcing steel which has been deformed mechanical properties have been changed and no standards anymore.

2.0 LITERATURE REVIEW

Z.T. Zhang and S. J. Hu (1997) had been calculating stress and residual stress methods in plane strain bending. The influence of deformation theory and incremental theory, repeating bending, unbending and re-bending, cyclic material models and springback calculation methods on the stress or residual stress distributions are examined and shown to be large [6]. H.X. Zhu (2006) had been compared the deformation theory, the flow theory with either isotropic hardening or kinematic hardening, and the shell theory (which ignores the transverse stress. The solutions reveal that large curvature bending can result in a significant thickness reduction of the bent plate, and therefore the non-dimensional bending moment initially increases with the non-dimensional bending curvature, reaches a peak point, and then drops with the further increment of the non-dimensional bending curvature [8].

2.1 Concrete reinforcement steel structures

Steel reinforcement for concrete construction is shaped steel round bars and deep for building construction materials. The manufacturing process begins with the raw material is steel molds (ingot / billet) which has soothed (normalizing). The next is the process of hot rolled forming process is then performed (metal forming) is the process of withdrawal and stretching. Shown in Figure 1 following the formation process Ingots / Billets into bars:

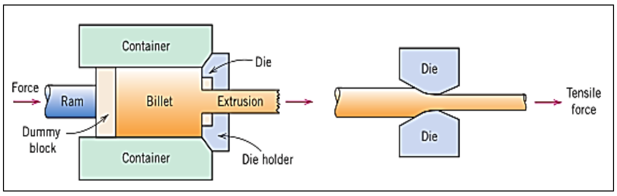

Figure 2: Metal forming process [4]

Based SNI 03-2847-2002, type of concrete reinforcing steel in outline are available in the market there are 2 types, namely plain bars (BJTP) and reinforcing steel screw or fins (BJTs). Following the classification of plain concrete reinforcing steel in the market as follows:

Table 1: Concrete Reinforcing Steel Size [7]

No.	Nomination	Nominal Diameter (D), mm	Nominal Area (A), cm²	Nominal Weight/meter (kg/m)
1	P.6	6	0,2827	0,222
2	P.8	8	0,5027	0,395
3	P.10	10	0,7854	0,617
4	P.12	12	1,131	0,888
5	P.14	14	1,539	1,12
6	P.16	16	2,011	1,58
7	P.19	19	2,835	2,23
8	P.22	22	3,801	2,98
9	P.25	25	4,909	3,85
10	P.28	28	6,158	4,83
11	P.32	32	8,042	6,31

2.2 Air Bending

Air bending is the bending process where the punch presses the workpiece and there is no reason to hold the workpiece when the movement is continued until the maximum punch [3]. There are two parameters of bending angle used, namely the bending angle alpha (α) and beta (β) as shown in Figure 2 below:

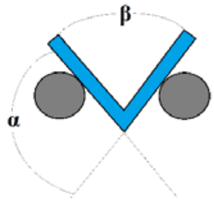

Figure 3. Bending angle parameters [3]

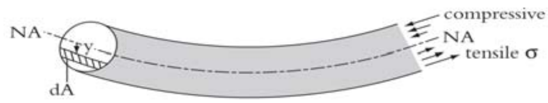

Figure 4: Schematic stresses occur at the positive bending [5]

When using a very sharp punch (compared to the sheet thickness), there is no need to explicitly model the contact between the sheet and the punch. It can be replaced by prescribed node displacement of the sheet in the vicinity of the symmetry axis [3].

2.3 Mechanical Properties of Materials

Mechanical properties of a material are a parameter in the design of the basic information of a material and the strength of the supporting data for material specifications. Mechanical properties of a material obtained from a tensile test results give a bigger picture than other mechanical testing, which includes parameters yield stress (deformation), tensile strength, tensile strength, strain, elastic modulus, the percentage of the length, the percentage reduction in the size, toughness , plasticity, elasticity, plasticity, yield type, and shape of fracture experienced by the material.

2.4. Tensile Test

Tensile testing was done to complete the design of the basic information of a material strength. In tensile testing, the specimen is loaded coaxial tensile force that grew continuously. Along with the observations made regarding the extension experienced by the test specimen.

$$\sigma = \frac{F}{A_o} \quad (1)$$

$$\varepsilon = \frac{\Delta L}{L_o} = \frac{L_i - L_o}{L_o} \quad (2)$$

Dimensions of the test specimen have been determined based on American Standard Testing and Material (ASTM) E8M that is shown in figure 5.

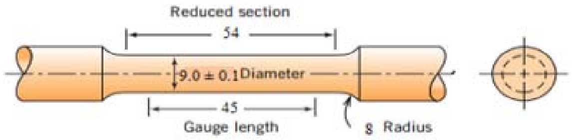

Figure 5: ASTM E8M [1]

The data was first generated from tensile testing machine is a drag curve. Furthermore, from these data are converted into engineering stress strain curve (using equations 1 and 2). Engineering stress strain curve result from tensile test data can be to find some sort of mechanical properties, among others:

2.4.1. Strength
It is the response of a material to a force per cross-sectional area of the working force in which it is granted [4]. Mechanical properties of tensile strength are further divided into three kinds of conditions based on engineering stress strain curve [4], namely:

a. Yield Strength (Yield Strength)
That is occurred at the beginning of the start of plastic deformation. Method of determining the yield strength is 0.002 of distance of its strain and takes the parallel line into the curve.

b. Maximum Tensile Strength
That is the maximum stress that occurs (curve peaks) in the engineering stress strain curve.

c. End Strength (Fracture Strength)
That last stress that occurs just before the specimen broke.

d. Modulus of elasticity
Elasticity is the ability of a material to return to its original shape when the applied force has been removed [4]. The modulus of elasticity is the value of the stiffness of a material in which the proportional ratio between stress and strain in the elastic region in the stress-strain curve is characterized by the slope of the curve.

c. Ductility (Ductility)
Ductility is a term to measure how much plastic deformation occurs until the material is dropped (Fracture) [2]. In the tensile test, ductility measured in two ways:

1. Reduction of Area

$$\% RA = \left(\frac{A_o - A_f}{A_o} \right) x100\% \quad (3)$$

2. Elongation

$$\% EL = \left(\frac{l_f - l_o}{l_o} \right) x100\% \quad (4)$$

3.0 METHODOLOGY

The methodology that used is experimental. The samples of material used is concrete reinforced steel structure production from PT. Krakatau Steel (Indonesia) is known enough to have credibility in issuing a product with consistent specifications. Steel structures are widely sold in the city of Pekanbaru and used in a variety of building construction.

3.1 Grouping Sample of Testing

Performed with varying bending angle, it is starting from the point (α) of 20°, 40°, 60°, 80°, 100°, 120°, 140°, 160°, 180°. The number of test specimens for each angle is not bent and bent test specimen is 5, so that for the test conditions are 45 test specimens. Total Specimens for tensile test specimens was 50.

3.2 Research Procedures

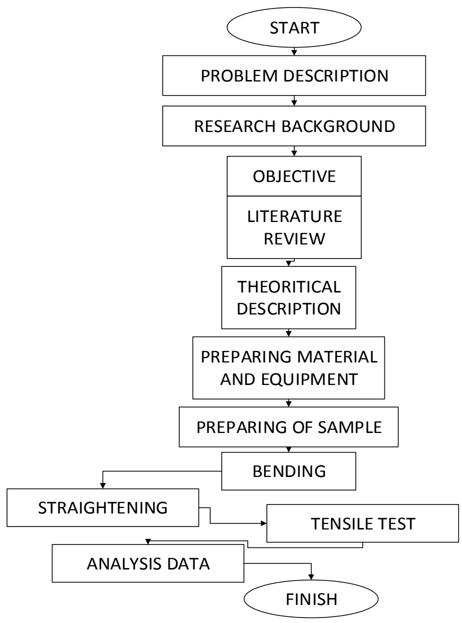

Figure 6: Flow Chart.

The first step is the process of cutting steel bars (12 mm of diameter) into 50 pieces. Once the cutting process was done, the process of turning at the central part of the specimen is to be ASTM E8M as shown in figure.7.


Figure 7: Preparing of samples

The next is making holes on each end of the specimen to the laying of the retaining pin when the tensile test. Furthermore, the bending process is carried out with nine variations of the bending angle. After the bending process, straightened out again with aligners were done. The results of the alignment are not perfect and this tends included in the sample treatment as shown in figure.8.


Figure 8: Bending and straightening

The curve resulting from tensile testing machine further processed to determine how much the yield strength and tensile strength.


Figure 9: Tensile Test

4. RESULTS AND DISCUSSION

After a series of tensile tests on each specimen, the initial data are curves tensile testing. Tensile curve further converted into engineering stress vs. strain using eq. (1) and eq. (2). The curve is then determined the value of the yield strength and tensile strength of the maximum value. From the data in get it is seen that the yield strength and maximum strength increases with increasing magnitude of the bending angle as shown in figure.10 and figure.11. Although there are some data that appears looks random, but the increase can be seen when the data are averaged. Tensile test data as follows:

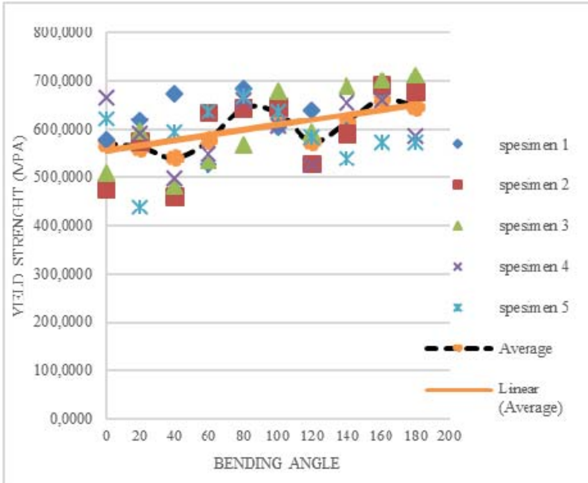

Figure 10: Yield Strength versus bending angel

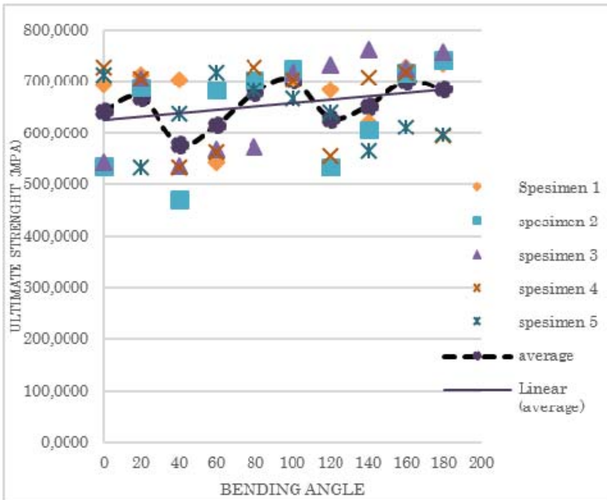

Figure 11: Ultimate tensile strength versus bending angle.

Data that has been averaged subsequently collected as shown in Table 2 as follow:

Table 6: The Average of tensile strength after bent

No	Bending Angle (α)	Yield Strength (Mpa)	Ultimate Tensile strength (Mpa)
1	0	571.3418	643.0496
2	20	564.2014	669.6719
3	40	542.4107	576.5689
4	60	577.5342	615.3892
5	80	645.3131	678.2813
6	100	635.0545	704.0271
7	120	574.8261	629.3563
8	140	614.9339	652.4639
9	160	662.9607	699.8821
10	180	649.1896	685.2347

The value of ductility was calculated using equation 3 and 4. The value increasing of tensile strength is caused by a strain hardening which increases the strength and lower ductility [8]. Evident from the data that the extension percentage value and reduction of area decrease as the size increases the bending angle. It is shown in Figure 11 and Figure. 12 as follows:

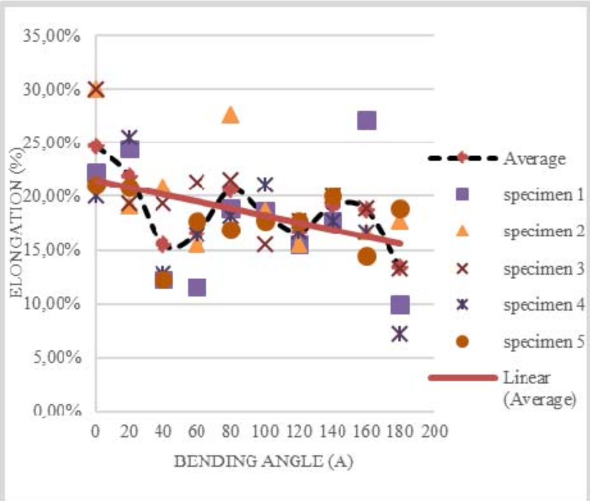

Figure 12: Elongation versus bending angle

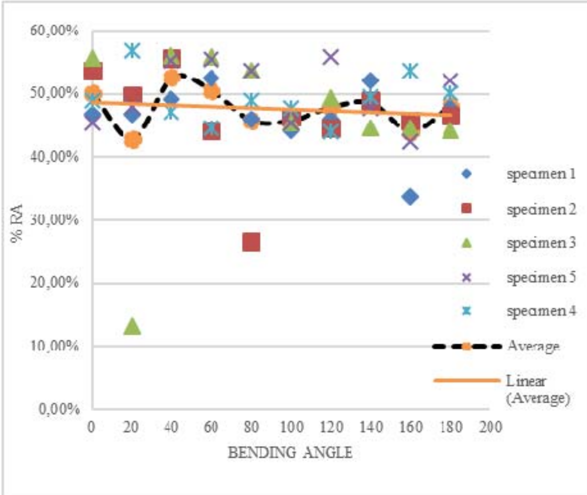

Figure 13: Reduction of area versus bending angle

The alteration of tensile strength at each bending angle can increase and can also decrease is shown In Table 7 as follows:

Table 7: Percentage alteration of strength.

Bending Angle	Yield (%)	Ultimate(%)
0	0%	0%
20	-1%	4%
40	-5%	-10%
60	1%	-4%
80	13%	5%
100	11%	9%
120	1%	-2%
140	8%	1%
160	16%	9%
180	14%	7%

5.0 CONCLUSION

Based on tensile test data, it can be concluded that the increasing percentage of the yield strength is 14% and the tensile strength is 7% on bending angle of 180 degrees alfa. The maximum decreased elongation is 13.42% (α = 180º) from 24.67% (α = 0º) and the reduction of area is decreasing 1.93 %. For the more result of accurate data should represent the number of samples multiplied.

ACKNOWLEDGEMENTS

The authors would like to convey a great appreciation to Universitas Riau for supporting this research.

REFERENCES

1. Annual Books of ASTM Standards. Metals Test Methods and Analytical Procedures. USA. Section Three, Volume 03.01. 1996.
2. Soboyejo, Wole, *"Mechanical Properties of Engineered Materials"*. New York: Marcel Dekker, 2002
3. D. Reche, J. Besson , T. Sturel, X. Lemoine, A.F. Gourgues-Lorenzon a. *Analysis of the air-bending test using finite-element simulation Application to steel sheets*. MINES Paris Tech, Centre des Mate ´riaux, CNRS UMR 7633, BP 87, 91003 Evry Cedex, France
4. William D. Callister, Jr., David G. Rethwisch, *"Materials Science and Engineering"*, ISBN 978-0-470-41997-7
5. Clifford, Michael, Richard Brooks, Alan Howe, Andrew Kennedy, Stewart McWilliams. 2009. *An Introduction to Mechanical Engineering: Part 1*. London: Hodder Education, An Hachette UK Company.
6. Z. T. Zhang, S. J. Hu. 1997. *Stress and residual stress distributions in plane strain bending*. Department of Mechanical Engineering and Applied Mechanics, University of Michigan, Ann Arbor, MI 48109, U.S.A.
7. SNI 03-2847-2002, SNI 07-2052-2002, *Indonesian Standard of Concrete reinforcing steel structure*.
8. H.X. Zhu. 2006. *Large deformation pure bending of an elastic plastic power-law-hardening wide plate: Analysis and application.* School of Engineering, Cardiff University, Cardiff CF24 OYF, UK
9. Arild H. Clausen, Odd S. Hopperstad, Magnus Langseth. 2001. *Sensitivity of model parameters in stretch bending of aluminum extrusions*. Elsevier Science Ltd: International Journal of Mechanical Sciences.