Effect of Bending Angle Variation to the Strength of Steel Reinforcement Bar

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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 so that it can be given the appropriate safety factors in the use of steel reinforced concrete structure. Concrete reinforcing steel bent structure with nine variations of the bending angle starting from the angle (α) of 20°, 40° , 60° , 80° , 100° , 120° , 140° , 160° , and 180°. The maximum value of the yield strength and tensile strength in the range of maximum bending process is 662.9607 and 704.0271 MPa in bending angle of 160 degrees and 100 degrees.

KEY WORDS: *Bending, Steel Structures, Mechanical Properties*

NOMENCLATURE

A□	Initial Area (mm²)
ΔL	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. Especially the construction of physical facilities in Riau Province is currently rising very rapidly, such as the construction of office buildings, bridges, apartments, hotels, plazas, shops, and residential-housing community. Construction of the physical facilities require 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. Most of the implementation of the concrete work in the field often encountered reuse of steel reinforcement has bent it.

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 andre-bending, cyclic material models and springback calculation methods on the stress or residual stressdistributions are examined and shown to be large [6].H.X. Zhu (2006) had been comparedthe deformation theory, theflow 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 asignificant 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 bendingcurvature[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:

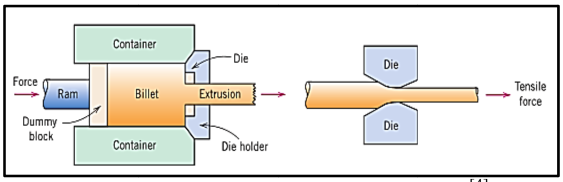

Figure 2. Metal forming process[4]

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

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, namely the bending angle alpha angle (α) and beta (β) as shown in Figure 2 below:

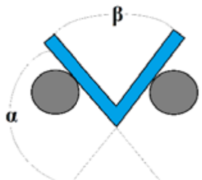

Figure 3. Bending angle parameters[3]

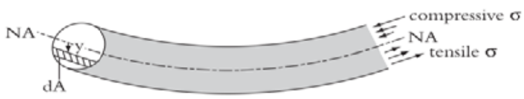

Figure 4. Schematic stresses occur at the positive bending[5]

When using a very sharp punch (compared to the sheetthickness), there is no need to explicitly model the contactbetween the sheet and the punch. It can be replaced byprescribed node displacement of the sheet in the vicinity ofthe symmetry axis[3].

2.3 Mechanical Properties of Materials

Mechanical properties of a material is 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 done to complete the design of the basic information of a material force. 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.

$$\sigma = \frac{F}{A} \tag{1}$$

$$\varepsilon = \frac{\Delta L}{L} = \frac{L - L}{L} \tag{2}$$

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

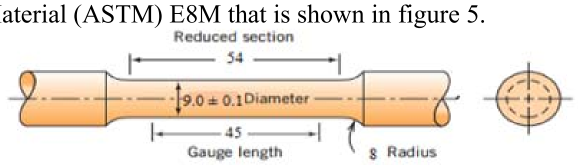

Figure 5. ASTM E8M[1]

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 is further divided into three kinds of conditions based on engineering stress strain curve[4], namely:

a. Yield Strength (Yield Strength)

That is occured at the beginning of the start of plastic deformation. The method of determining the yield strength is 0.002 distance of its strain and take the paralel 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 are characterized by the slope of the curve.

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} \tag{3}$$

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

$$\% RA = \left(\frac{A_o - A_f}{A_o} \right) x100\% \tag{4}$$

2. Elongation

$$\% EL = \left(\frac{l_f - l_o}{l_o} \right) x100\% \tag{5}$$

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°, then straightened back and done testing to obtain tensile mechanical properties. 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. Specimen which is bent so that the amount of the 45 specimens, and are not bent as much as 5 specimens. Total Specimens for tensile test specimens was 50.

3.2 Research Procedures

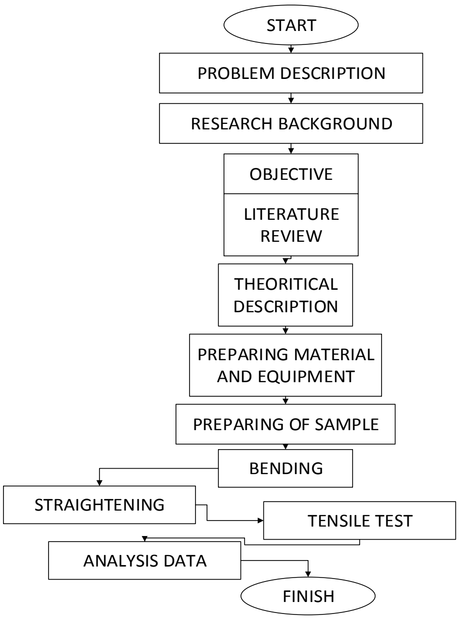

Figure 6. Flow chart

The first step is the process of cutting steel bars (12 mm of diameter) into 50 pieces. Once that is done the process of turning the central part of the specimen to be ASTM E8M (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, then straightened out again with aligners. the results of the alignment is not perfect and this tends included in the sample treatment (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. 0 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. The curve is then determined the value of the yield strength and tensile strength of the maximum value.Tensile test data as follows:

Table 2. Yield strength after bent for each spesimen

No.	Bending Angle				
	0	20	40	60	80
Spec. 1	579.1983	618.7636	672.9798	528.1237	683.8457
Spec. 2	478.9057	575.4722	462.5709	636.0085	646.0013
Spec. 3	508.9326	596.4624	483.4772	535.5261	567.1252
Spec. 4	665.8346	592.1073	497.9339	550.8817	661.6460
Spec. 5	623.8377	438.2014	595.0918	637.1309	667.9474
Aver.	571.3418	564.2014	542.4107	577.5342	645.3131

Table.3: Yield strength after bent for each specimen *(continued)*

Bending angle *(Continued)*				
100	**120**	**140**	**160**	**180**
604.9335	640.3582	595.4814	684.3799	695.7560
647.3392	528.6524	592.3307	693.1530	678.7480
678.1649	594.7019	689.3138	702.1982	712.0572
607.2365	527.4709	657.1029	661.6460	586.0294
637.5983	582.9470	540.4405	573.4266	573.3576
635.0545	574.8261	614.9339	662.9607	649.1896

Tabel.4: Ultimate Tensile Strenght after bent for each specimen

No.	Bending Angle				
	0	**20**	**40**	**60**	**80**
Spec. 1	693.8313	711.8786	702.0991	542.7938	702.6671
Spec. 2	537.5086	689.3678	471.5820	683.4201	703.8014
Spec. 3	544.3647	705.7154	537.1969	568.9965	573.4266
Spec. 4	727.4860	706.1658	534.3681	563.4018	727.8107
Spec. 5	712.0572	535.2317	637.5983	718.3339	683.7009
Aver.	643.0496	669.6719	576.5689	615.3892	678.2813

Table.5: Ultimate Tensile Strenght after bentfor each specimen *(Continued)*

Bending angle (continued)				
100	**120**	**140**	**160**	**180**
705.7558	683.0487	621.3171	726.7127	734.4091
723.7869	534.6598	607.4541	718.3586	742.0978
718.2383	732.4223	760.1779	724.7458	756.1669
704.3943	556.0163	708.6404	718.3586	595.4814
667.9601	640.6345	564.7299	611.2349	598.0181
704.0271	629.3563	652.4639	699.8821	685.2347

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

Table.6: Tensile strenght after bent

No.	Bending Angle (α)	Yield Strenght (Mpa)	Ultimate Tensile Strenght (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

In these data can be seen that the yield strength and ultimate tensile strenght decreases in certain pembnegkokan corner and climb back on a certain bending angle.And then, the correlation between tensile strenght and bending angles as follows:

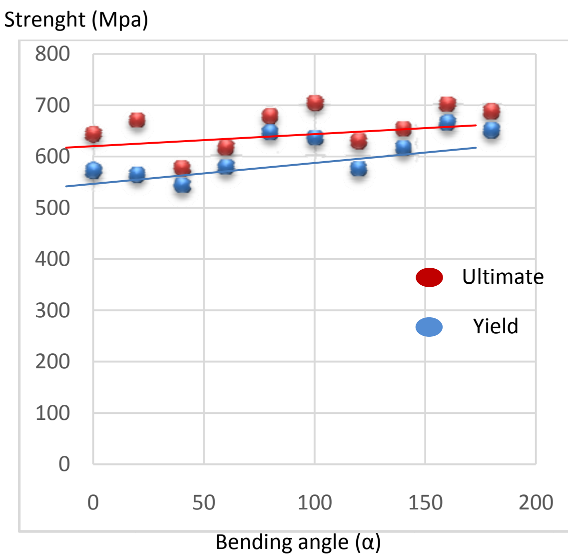

Figure.11: Strength vs Bending angle

Percentage the percentage is increased, and if the value is negative then decreased change in tensile strength at each bending angle can go up and can also go down . In table 7 is shown if the value is positive then

Table.7: Percentage change of mechanical properties

Bending Angle	Yield (%)	Ultimate(%)	Elongation (%)
0	0%	0%	24.67%
20	-1%	4%	22%
40	-5%	-10%	15%
60	1%	-4%	17%
80	13%	5%	21%
100	11%	9%	18%
120	1%	-2%	17%
140	8%	1%	19%
160	16%	9%	19%
180	14%	7%	13%

but with the increase in yield strength and ultimate strength , resulting in lower ductility due to strain hardening has occurred , as shown in the Figure 12 as follows:

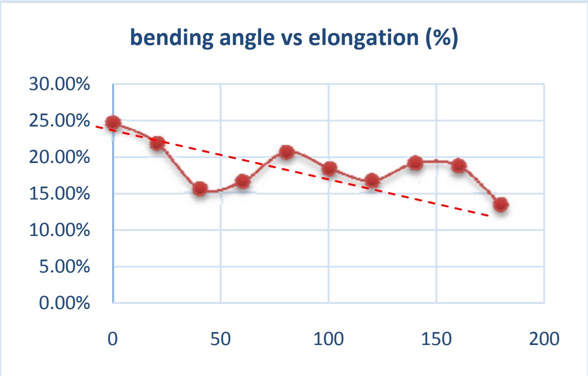

Figure 12: Bending Angle vs Elongation

5.0 CONCLUSION

Based on tensile test data, it can be concluded that the yield strength and ultimate strenght impaired at an angle of 20 degrees bending and again increased at an angle of 80 degrees and 100 degrees, and again increased at an angle of 160 degrees to 180 degrees. The maximum value of the yield strength and tensile strength in the range of maximum bending process is 662.9607 and 704.0271 MPa in bending angle of 160 degrees and 100 degrees. The meximum decreased elongation is 11.67 % at bending angle 180 degrees. For the more result of accurate data should represent the number of samples multiplied.

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