CHAPTER 04

4.0 CALCULATION AND DISCUSSION

4.1 0.2% Offset yield stress in tensile testing

As per litreature review (Pg 25) yield stress was calculated for CTD and TMT bars and tabulated in the table 06.

4.2 0.05% Offset yield stress in three point bending.

In accordance with ASTM E855-90 [13] applies to three point bending at smaller strains for spring applications,Certain elastic /plastic data may be obtained from load-displacement (position) curves in three point bending including 0.05% offset yield, the elastic limit and the elastic modulus in bending. A typical example for calculating 0.05% offset yield stress for 12 mm diameter of CTD and TMT are shown in fig.15 & fig.16. However,0.05% offset yield in bending measured on many samples shows higher yield values and in some cases go beyound maximum stress in tensile strength.

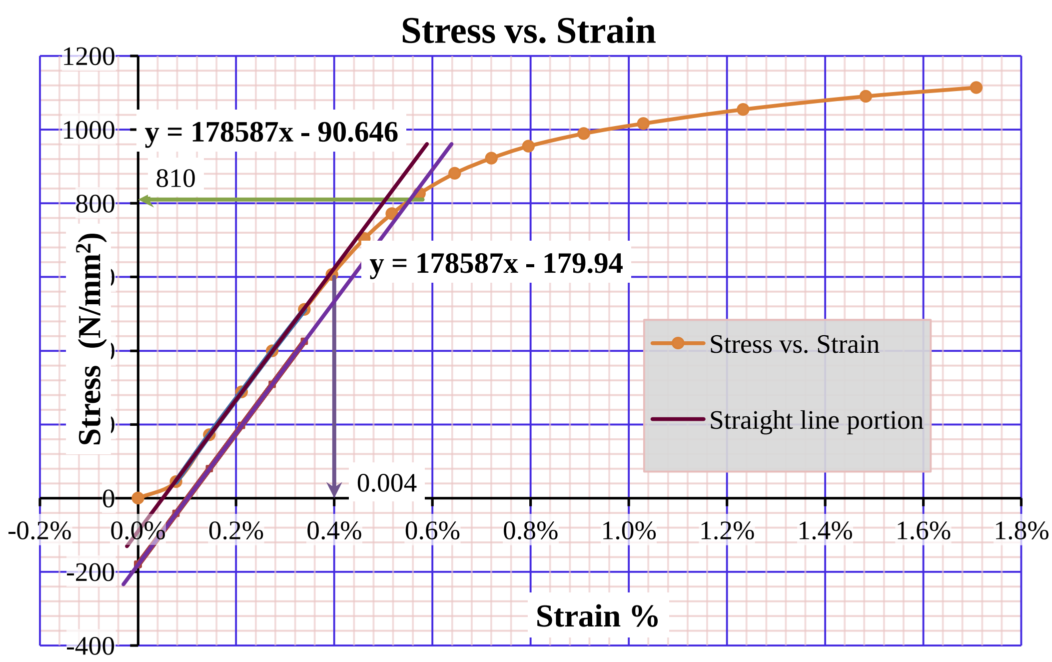


Fig.15 Stress Vs Strain in three point bending including 0.05% offset yield for CTD bars.

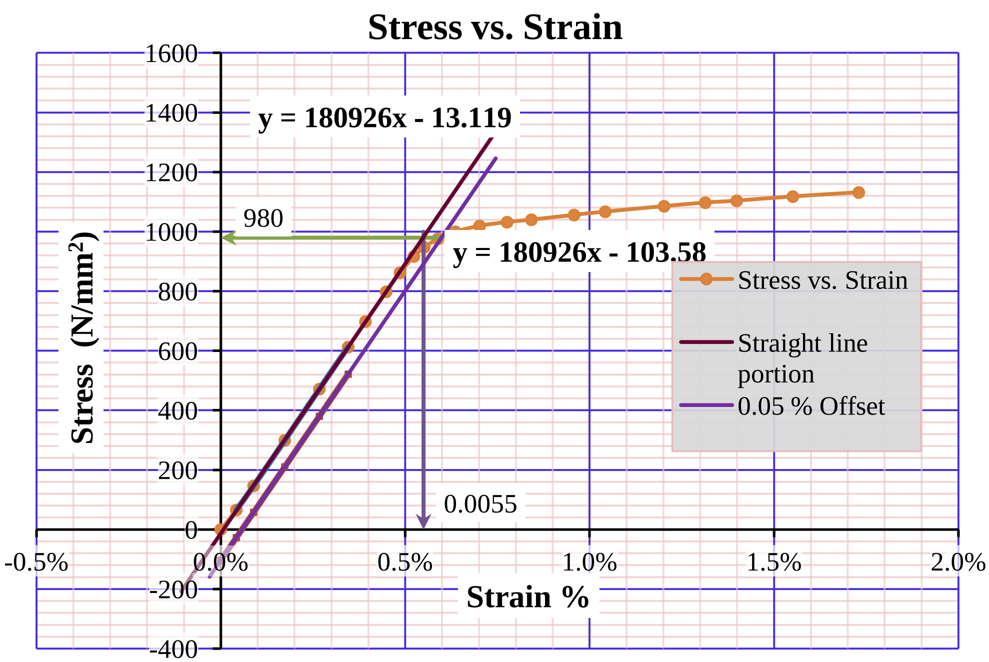


Fig.16 Stress Vs Strain in three point bending including 0.05% offset yield for TMT

4.3 0.04% Offset yield stress in three point bending.

As per the NBRO testing data of tensile test, it was observed that, the ratio of stress at elastic limit and 0.2% proof stress is 1.10. It was shown that, ratio of 0.04% Offset bend stress value and stress at elastic limit in three point bend test also follows the trends in the data measured in the tensile test of NBRO.Therfore,0.04% offset bend stress was calculated for all the bars tested.

Figure 17 & figure 18 show typical examples for calculating 0.04% offset yield in bending for CTD and TMT 12mm diameter bars.

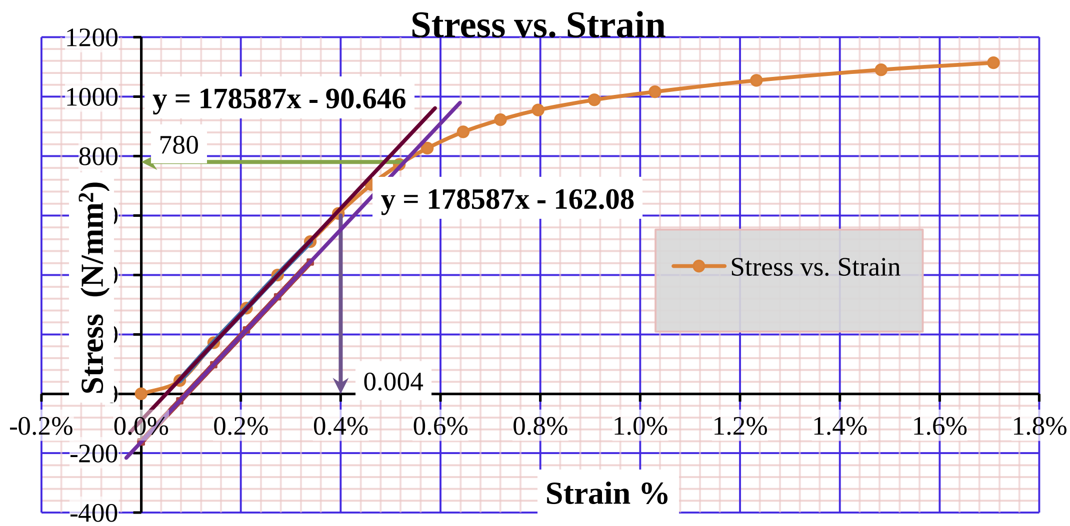


Fig.17 Stress Vs Strain in three point bending including 0.04% offset yield for CTD bars.

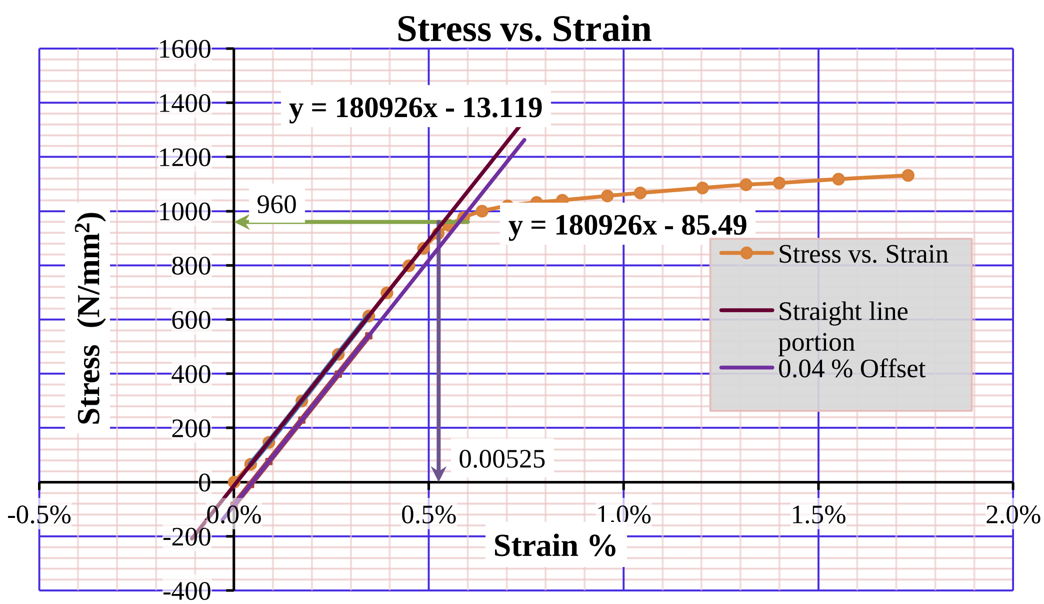
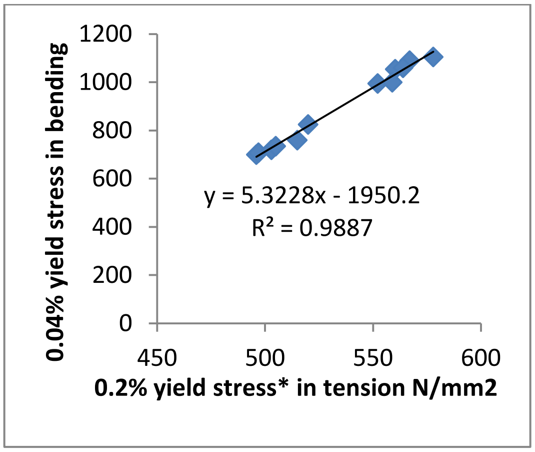


Fig.18 Stress Vs Strain in three point bending including 0.04% offset yield for TMT bars.

Next to correlate the 0.2% offset yield stress that was measured in the tensile test was plotted against the 0.04% offset bend stress measured in bending for 10mm to 32mm diameter of CTD and TMT bars are shown in fig.19 to fig.24. By fitting these data to a straight line, a correlation in CTD bars and TMT bars were determined to relate the 0.2% proof stress in tension and 0.04% Offset yield stress in three point bending. Yield stresses are given in table 05.Good correlations were obtained for individual bar diameters and shown bellow.



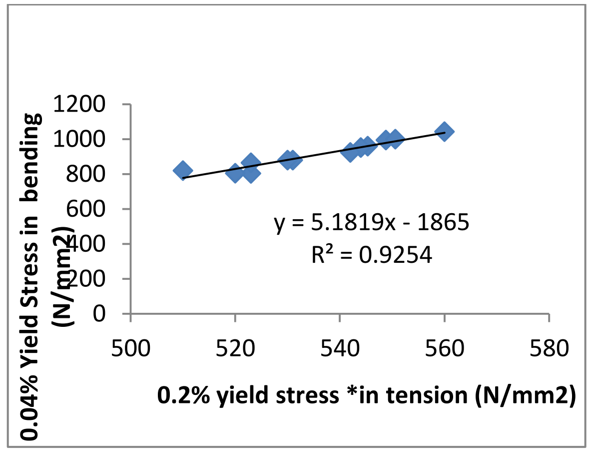
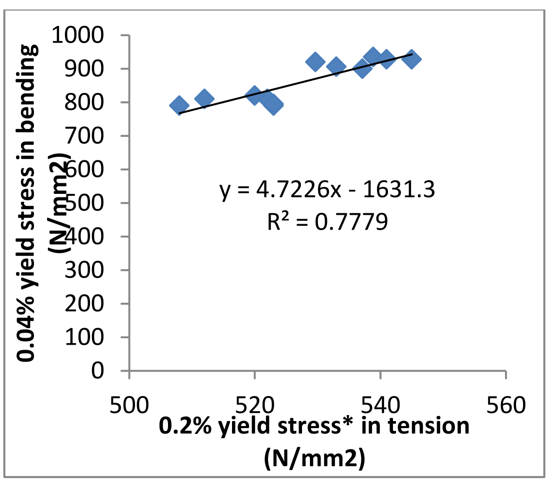


Fig.19: 0.04% yield stress in bending Vs 0.2% Yield Vs Stress* in tension -10mm dia. Bars.

Fig.20: 0.04% yield stress in bending 0.2% yield Stress* in tension -12mm dia. Bars.



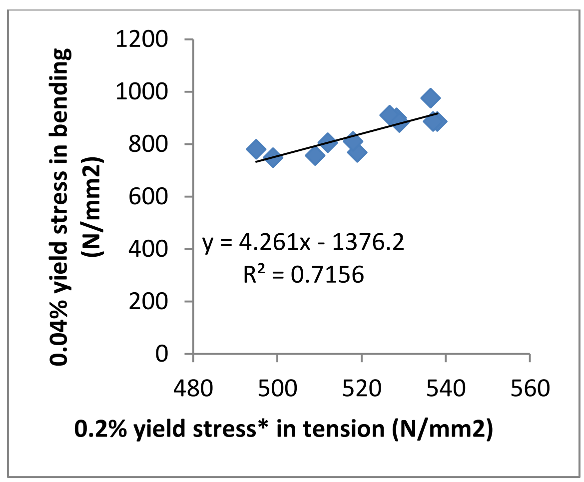
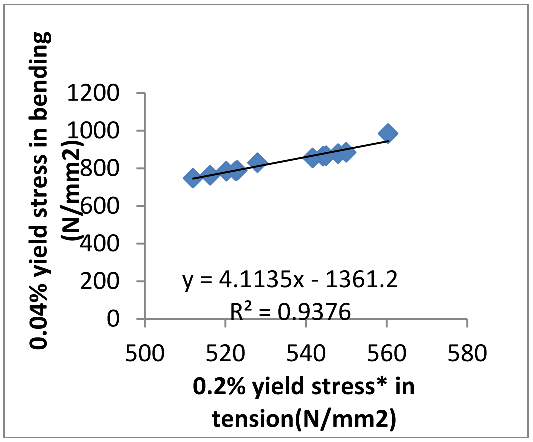


Fig.21: 0.04% yield stress in bending Vs 0.2% Yield Stress* in tension -16mm dia. Bars.

Fig.22: 0.04% yield stress in bending Vs 0.2% Stress* in tension -20mm dia. Bars.

Note: * Upper Yield stress for thermal treated bars (TMT)



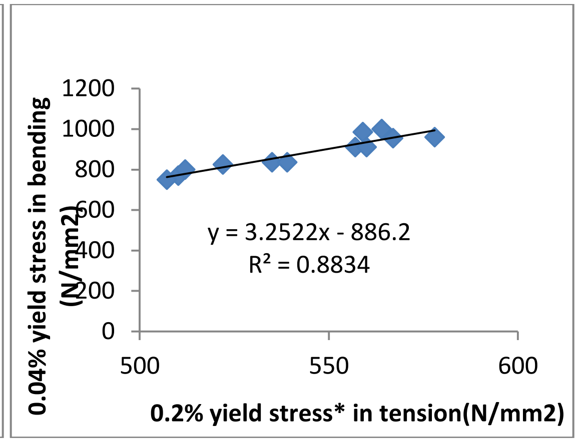


Fig.23: 0.04% yield stress in bending Vs 0.2% Yield Stress* in tension -25mm dia. Bars.

Fig.24: 0.04% yield stress in bending Vs 0.2% Yield Stress* in tension -32mm dia. Bars.

Note: * Upper Yield stress for thermal treated bars (TMT)

The above relations may vary as per the test methods and equipments used. Having this in mind following calculation was carried out for the linear equations obtained for different bar diameters.

Table 3 : Relationship between gradient (m) and intercept (c) drive from the equations obtained from σ_b Vs σ_t
(Where, σ_b - 0.04% yield stress in bending and σ_t - 0.2% yield stress in tensile)

Nominal Bar Diameter(mm)	**Span (mm)**	**Span/Mandrel Diameter(S)**	**m**	**C**
10	200	8.0	5.322	-1950.2
12	240	9.6	5.182	-1865.0
16	320	12.8	4.723	-1631.3
20	400	16.0	4.261	-1376.2
25	500	20.0	4.114	-1361.2
32	640	25.6	3.252	-886.2

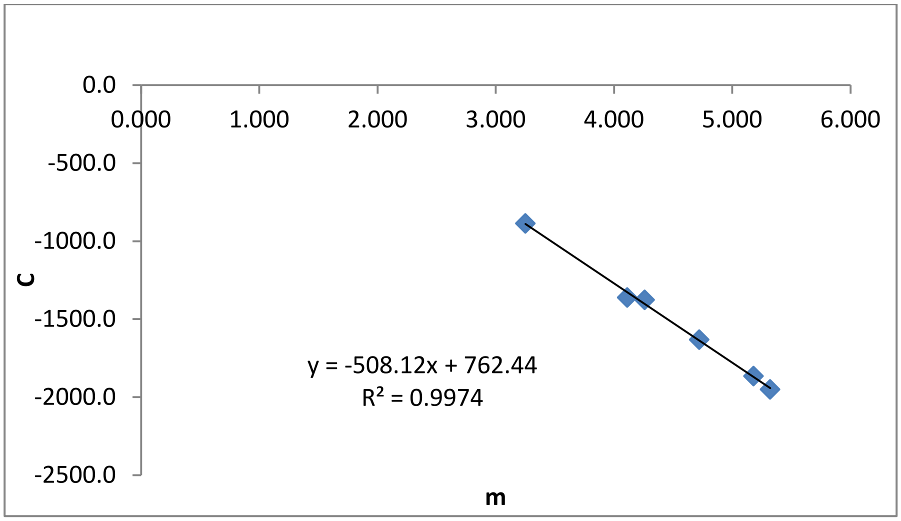


Figure 25: Intercept © Vs gradient (m) 0f σ_b & σ_t

The linear relation was observed and $c = m_1\ m + c_1$ Where, $c = m\ \sigma_t - \sigma_b$

Therefore,- $\sigma_b + m\ \sigma_t = m_1\ m + c_1$, $m\ \sigma_t = -508.12m + 762.44 + \sigma_b$

$m\ \sigma_t = \sigma_b - 508.12\ m + 762.44$

The above graph shows a liner relationship between σ_b & σ_t if **m** is constant. But, 'm' may depend on many factors such as span, mandrel diameter and steel bar diameter.

The relationship observed for m Vs bar diameter is as follows

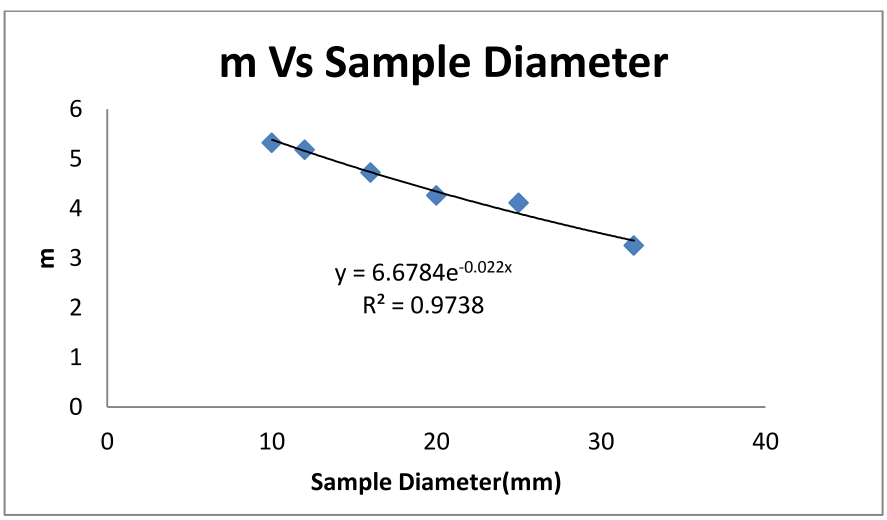


Figure 26: m Vs sample diameter

The above graph was plotted 'm' vs sample diameter. Since the exponential equation is like y=a{exp(bx)} , we can assume 'b' to be a value with inverse length units so that part inside exp function is dimensionless. Note that in graphs of σ-t vs σ-b the gradient is a dimensionless factor which is the stress gain while intercept is the threshold stress. In graph of m vs diameter, 'a' is a dimensionless quantity while 'b' is an inverse length parameter.

It can be observed that for all diameters tested, there is a definite linear relationship between the bending yield strength and tensile yield strength. In addition there is a linear relationship between the stress gain and the threshold stress values for all diameters tested as shown by the Stress gain vs threshold stress graph. This shows that the relationship between bending stress and tensile yield stress is definite and predictable for any diameter within the range of tests conducted. It can also be seen from the graph of Stress gain vs sample diameter that there is a definite and predictable relationship between the diameter of the sample and the stress gain, which is exponential in nature. This concludes that knowing the sample size and bending yield stress, it is possible to predict the tensile yield stress.

The accuracy of this prediction was determined by using t- analysis for the observed 0.2% proof yield stress and for the calculated yield stress by using the equation obtained for the different bar diameters.

Table 4: Summary of Statistical Calculation

Bar. Diameter	σ(Square root of variance between 0.2% proof yield stress and calculated yield stress using the equations for different bar diameters)	T-Calculated	T-Table 95%
10	32.72	0.01	
12	15.31	0.75	
16	12.10	0.77	1.76
20	12.10	0.77	
25	14.74	1.09	
32	12.10	0.77	

Analysis shows that the all the calculated t-values are below the table value. Therefore, it can be stated that the tensile yield stress calculated from bending yield stress are accurate within 95% confidence level.

4.4 Rib geometry

The degree of cold twisting of CTD steel bars may have an influence on the tensile and bending properties of the bar due to case hardening. Assuming that the degree of twisting will be reflected by the pitch of the longitudinal rib, the relationship between the pitch to bar diameter ratio and the 0.04% 0ffset bend stress was examined from the test results given in table 5.

It is seen from figures 27 and 28 that there was no significant linear or exponential correlation between the 0.04% bend offset stress and the pitch to bar diameter ratio because the correlation coefficient R obtained in both cases were rather low (0.3&0.29).

Thus it may be concluded that the pitch to bar diameter ratio has no significant influence on the 0.04% offset bend stress.

Table 5: 0.04% Offset bend stress value Vs Pitch/Diameter ratio

Nominal Diameter(mm)	Pitch(mm)	Pitch/Diameter Ratio	0.04% offset bend stress (N/mm^2)
10	110	11	665
12	120	10	804
16	203	13	790
20	217	11	748
25	235	09	845
32	345	11	825

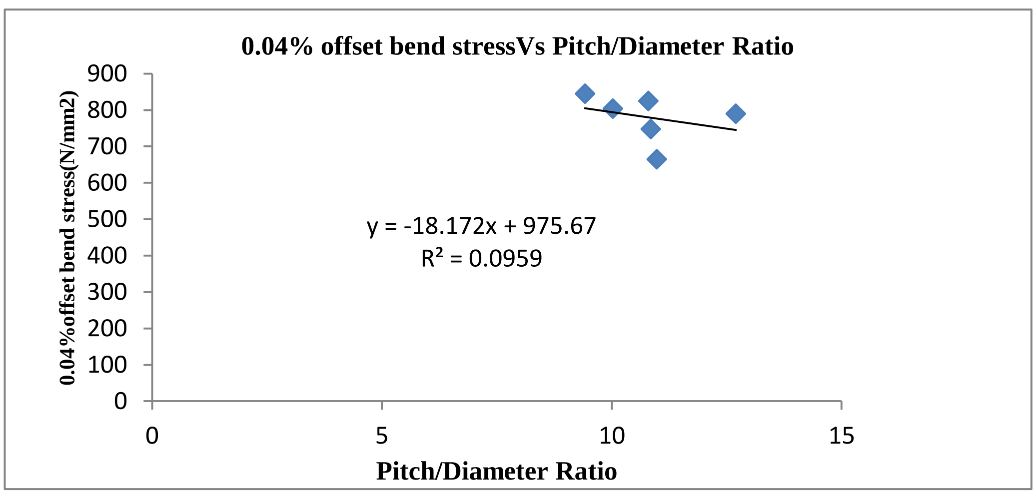


Figure 27: 0.04% Off set bend stress Vs Pitch/Bar Diameter Ratio – Linear Relationship

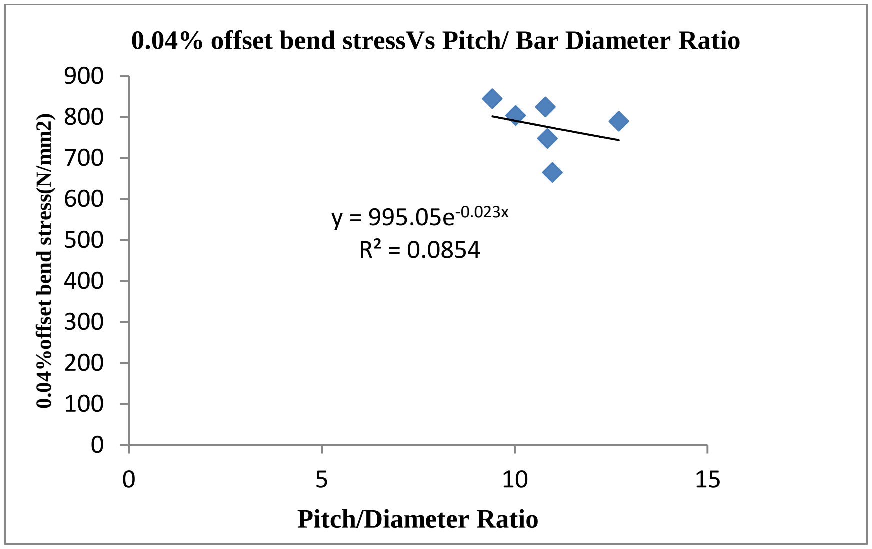


Figure 28: .0.04% offset bend stress Vs Pitch/Bar Diameter Ratio- Exponential Relationship

CHAPTER 05

5.0 Conclusion

Three point bend testing and tensile testing were performed on Cold Twisted reinforced bars and Thermo Mechanical Treated bars of 10mm diameter to 32mm diameter. The following were concluded.

1. Using the experimental data obtained for reinforcement steel bars subjected to tensile testing shown, that the 0.2% yield (proof yield) stress can be measured from 0.04% offset yield stress measured from three point bend load displacement (Position) curves.
2. Result of three point bend testing and tensile testing show different relationships for different bar diameters, which are exponentially related.
3. Extent of work hardening measured by means of pitch value of rib geometry test does not show a clear relationship with 0.2% proof stress in tensile testing for different bar diameters.

Although the three points bend test results, show good relations with tensile yield stress measured, ductility and durability tests are also very important for compliance of the test result in accordance to the design guild lines.

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