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Influence of Chemical Parameters on the Mechanically Treated Hot Rolled Bar Used in Construction

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Abstract : *The bar rod samples from different industries were obtained in order to check the good quality of bar rods which are used in construction of buildings, bridges etc. The chemical properties of 20 samples were examined using Optical Emission Spectroscopy as well as wet analysis as per IS:228(Part 3)-1987, IS:228(Part 4)-1987, IS:228(part 9)-1989 and the yield stress and tensile strength of the samples were compared with the concentration of the elements present in the samples.*

Keywords: *Bar rods, Mechanical Properties, Optical Emission Spectroscopy, Percentage Elongation, Ultimate Tensile Strength, Yield Stress,*

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1. INTRODUCTION

The hot-rolled bars of mild steel of cross-section either circular or square, which are known as bar rods. The mild steel consists of several chemical elements which includes iron, copper, carbon, sulphur, phosphorus, chromium, nickel, tungsten, etc. Majority of mild steel bar rods are incorporated in concrete for reinforcing purpose in order to increase the tensile strength of the structure. According to IS:432(Part 1)-1982, the diameter of the mild steel bar rods ranges from 5mm to 50mm. But bar rods are found from 3mm to 350 mm in the market. There are various specifications for bar rods which include Fe 500, Fe500 D, Fe 550D etc. These bar rods are classified into various types, based on its shape, such as round, square, hollow bars, etc. Bar rods are stronger and light in weight.

Bar rods are used in construction of roads, buildings, dams, bridges and many structures. A wide range of bar rods are used in construction of heavy equipment ranging from small scale to heavy chemical processing plants, where the components are exposed to wide range of temperatures, pressures and various chemicals. Failure of equipment and structures occurs if the quality of material of construction is not maintained up to the mark. Bar rods are quite extensively used of Fe500D. The composition of material of construction contributes towards the tensile strength, yield stress [1,2], percentage elongation, corrosion resistance etc. These elemental percentages also decide the ductility, strength, creep resistance, fragileness, temperature stability. if any failure occurs the root cause analysis is made over the composition of the bar rods for elemental analysis of the alloys, since each element percentages impacts the physical and mechanical properties of the bar rod. According to IS1786:2008, the chemical analysis of bar rods of elements carbon, sulphur, phosphorus is mentioned in the table 1.

II. OBJECTIVE

As per literature survey, there are many articles regarding the microstructure and the mechanical properties of the bar rods, this article sheds the light over the quality parameters of bar rods which are used in different sectors

Table 1 Physical and Mechanical properties of Fe500D bar rod according to IS1786:2008

S. No.	Characteristics		
1		Element	Percentage (maximum)
	Chemical	Carbon	0.25
		Sulphur	0.04
		Phosphorus	0.04
		Sulphur and phosphorus	0.075
2		Property	N/mm^2 (minimum)
	Physical	Ultimate tensile strength (N/mm^2)	565
		Yield Stress (N/mm^2)	500
		Percentage elongation(%)	16

III. EXPERIMENTAL PROCEDURE

The bar rod samples of Fe 500 D were tested over Optical Emission Spectroscopy (OES)[3,4] for chemical composition of samples. The figure of Optical Emission Spectroscopy, standards for calibration and the electrode for iron-based samples is displayed in figure 1. The result obtained contains 26 elements of concentration up to 0.0001%. This process is fast and accurate when compared to other processes. The concentration of carbon, sulphur, and phosphorus in the samples were also analyzed using wet analysis according to IS228. The results obtained from both the processes (OES and Wet analysis) were almost similar. The results of 20 samples from the OES is listed in the table 2 and 3.

IV. RESULTS AND DISCUSSION

When the elements carbon, Sulphur, phosphorous are observed, even in small change in concentration, contributes a great change to the ultimate tensile strength and the yield stress of the samples, while all other elemental concentration is almost observed constant, and it is observed that the increase in concentration of carbon, Sulphur, and phosphorus content, there is a decrease in value of ultimate tensile strength, yield stress [5] of the samples tested. According to IS 1786:2008, for Fe500D the carbon concentration should be 0.25%, Sulphur's 0.04%, phosphorus's 0.04%; as observed in the table 1, as carbons concentration is moving closure to 0.25%, the ultimate tensile strength and the yield stress of the respective samples decreasing from figure 2 and igure 3 if observed simultaneously. The carbon concentrate on for sample "A2" is 0.15%, which was observed the lowest in all the samples, and the highest was 0.26% for sample A19 and the ultimate tensile strength reported was 660 and 561 N/mm^2 respectively and yield stress observed was 598 and 490 N/mm^2 respectively and rest of the samples, the tensile strength fall in between 660 to 561 490 N/mm^2 and for yield stress it is in between 598 to 490 490 N/mm^2 . If the results of sample "A19" were observed, the chemical properties were found to be exceeding the limits as per given in IS1786:2008 and the resulting tensile strength and yield stress of Fe500D tested according to IS1608:2005were declined below 565 and 500 N/mm2 .The increase in carbon equivalent percentage, increase in hardness was observed [6]. As represented in figure 4, the sample with higher CE percentages possess greater hardness relatively.

As the rebars are thermomechanically treated (TMT), the hot rebars are quenched by several water jets and then tampered resulting in its martensite outer layer and the soft inner layer because of its ferrite and pearlite structure, so the resulting rebars possess high bendability.

Since most of the construction structures are reinforced with TMT rebars, the rebars should possess good mechanical properties like high tensile strength, yield stress, ductility, hardness in order to resist the failure due to earth quakes and shocks. In order to possess these properties, the concentration of carbon and carbon equivalent should be maintained accordingly.

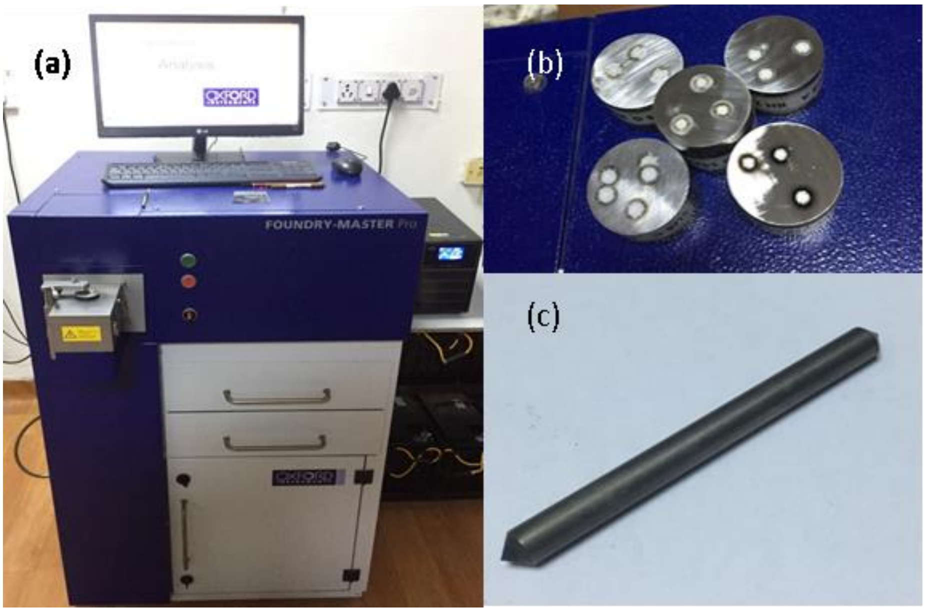

Fig. 1 (a) Optical Emission Spectroscopy (b) Standards for Calibration (c) Electrode for iron-based samples

Table 2 Chemical composition of samples A1-A10

Sample id / Elements	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
Fe	98.5	98.5	98.7	98.5	98.8	98.7	98.9	98.8	98.5	98.7
C	0.165	0.15	0.159	0.209	0.193	0.198	0.192	0.193	0.204	0.2
Si	0.154	0.159	0.217	0.285	0.185	0.193	0.143	0.184	0.159	0.225
Mn	1.06	1.07	0.811	0.844	0.785	0.796	0.731	0.793	1.04	0.796
P	0.022	0.0205	0.0191	0.0241	0.0103	0.0107	0.0184	0.0107	0.023	0.0189
S	0.012	0.0102	0.0207	0.0367	0.0131	0.0149	0.0152	0.0127	0.0117	0.0214
Cr	0.0105	0.0099	0.0092	0.0102	0.013	0.0123	0.013	0.0134	0.0096	0.0058
Mo	0.001	0.001	0.0016	0.0011	0.001	0.001	0.001	0.001	0.001	0.001
Ni	0.0028	0.0021	0.0016	0.0018	0.0022	0.0021	0.0041	0.0033	0.0034	0.0018
Al	0.001	0.001	0.001	0.001	0.001	0.0104	0.001	0.001	0.001	0.001
Co	0.0029	0.0027	0.0023	0.0025	0.0039	0.0039	0.0046	0.004	0.0031	0.0025
Cu	0.001	0.001	0.001	0.001	0.001	0.001	0.0016	0.001	0.001	0.001
Nb	0.001	0.0012	0.0013	0.001	0.001	0.001	0.0011	0.001	0.001	0.001
Ti	0.0026	0.0024	0.0015	0.0005	0.002	0.0027	0.0023	0.0019	0.0018	0.0017
V	0.002	0.0019	0.0014	0.002	0.0016	0.0016	0.0018	0.0017	0.0024	0.0013
W	0.005	0.005	0.005	0.0053	0.005	0.005	0.005	0.005	0.005	0.005
Pb	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Sn	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
B	0.0003	0.0003	0.0006	0.0009	0.0007	0.0007	0.0007	0.0007	0.0006	0.001
Ca	0.0001	0.0001	0.0001	0.0001	0.0008	0.0004	0.0002	0.0005	0.0001	0.0004
Zr	0.003	0.003	0.0029	0.003	0.0024	0.0021	0.0022	0.0029	0.0028	0.0026
Zn	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Bi	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
As	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N	0.002	0.003	0.002	0.002	0.0107	0.0085	0.013	0.0118	0.0082	0.0078
Se	0.0014	0.0029	0.0014	0.001	0.003	0.0018	0.0023	0.0027	0.0027	0.0026
Sb	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
Ta	0.0247	0.023	0.0241	0.0242	0.005	0.005	0.005	0.005	0.005	0.005
CE	0.34	0.33	0.3	0.35	0.33	0.33	0.32	0.33	0.38	0.33

Table 3 Chemical composition of samples A11-A20

Sample id	Carbon	Phosphorus	Sulphur	Tensile Strength (N/mm2)	Yield Stress (N/mm2)
A1	0.165	0.022	0.012	661	596
A2	0.15	0.0205	0.0102	660	598
A3	0.159	0.0191	0.0207	661	596
A4	0.209	0.0241	0.0367	653	592
A5	0.193	0.0103	0.0131	657	595
A6	0.198	0.0107	0.0149	656	594
A7	0.192	0.0184	0.0152	657	595
A8	0.193	0.0107	0.0127	657	595
A9	0.204	0.023	0.0117	652	591
A10	0.2	0.0189	0.0214	653	592
A11	0.205	0.0193	0.0221	652	591
A12	0.193	0.0186	0.0194	657	595
A13	0.19	0.0186	0.0195	657	595
A14	0.208	0.0132	0.022	653	592
A15	0.218	0.0127	0.0089	651	588
A16	0.205	0.0131	0.0088	652	591
A17	0.206	0.0125	0.0114	652	591
A18	0.212	0.0132	0.0105	650	589
A19	0.26	0.039	0.041	561	490
A20	0.217	0.0217	0.019	651	588

Note: Fe-Iron, C-Carbon, Si- Silicon, Mn-Manganese, P- Phosphorus, S- Sulfur, Cr- Chromium, Mo-Molybdenum, Ni-Nickel, Al- Aluminum, Co-cobalt, Cu-Copper, Nb- Niobium, Ti-Titanium, V-Vanadium, W-Tungsten, Pb-Lead, Sn-Tin, B-Boron, Ca-Calcium, Zr- Zirconium, Zn- Zinc, Bi- Bismuth, As- Arsenic, N-Nitrogen, Se- Selenium, Sb- Antimony, Ta-Tantalum, CE- carbon Equivalent

Table 4 The concentration of Carbon (C), Phosphorus (P), Sulphur (S) by OES and tensile strength, yield stress of the tested samples.

sample id / element	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
Fe	98.7	98.7	98.7	98.7	98.3	98.3	98.3	98.3	98.3	97.8
C	0.205	0.193	0.19	0.208	0.218	0.205	0.206	0.212	0.26	0.217
Si	0.23	0.217	0.224	0.02	0.0244	0.0268	0.0273	0.0244	0.0304	0.0378
Mn	0.794	0.793	0.8	0.761	1.29	1.28	1.29	1.29	1.3	1.39
P	0.0193	0.0186	0.0186	0.0132	0.0127	0.0131	0.0125	0.0132	0.039	0.0217
S	0.0221	0.0194	0.0195	0.022	0.0089	0.0088	0.0114	0.0105	0.041	0.019
Cr	0.007	0.0133	0.015	0.01	0.0116	0.0124	0.0116	0.012	0.012	0.0244
Mo	0.001	0.0011	0.001	0.0013	0.0024	0.0025	0.0019	0.0021	0.0018	0.0015
Ni	0.0034	0.0039	0.013	0.0036	0.0075	0.0085	0.0079	0.0079	0.0083	0.0064
Al	0.001	0.001	0.001	0.001	0.0069	0.0034	0.001	0.0048	0.0034	0.002
Co	0.0025	0.0025	0.0025	0.0028	0.003	0.0029	0.0031	0.0032	0.0031	0.0032
Cu	0.001	0.001	0.001	0.001	0.0018	0.0017	0.0015	0.0017	0.0021	0.0011
Nb	0.001	0.001	0.001	0.0015	0.0142	0.0135	0.0135	0.0146	0.0145	0.0208
Ti	0.0016	0.0016	0.0017	0.0017	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
V	0.0015	0.0014	0.0017	0.0014	0.0232	0.0231	0.0226	0.0233	0.0241	0.0283

W	0.005	0.005	0.005	0.005	0.0051	0.005	0.005	0.0081	0.0055	0.005
Pb	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Sn	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
B	0.001	0.0009	0.0009	0.0005	0.0002	0.0003	0.0003	0.0004	0.0004	0.0006
Ca	0.0013	0.0004	0.0001	0.0002	0.0018	0.0023	0.0016	0.0019	0.008	0.0009
Zr	0.003	0.0028	0.0026	0.0014	0.001	0.0032	0.0011	0.0013	0.0014	0.0024
Zn	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Bi	0.001	0.001	0.001	0.001	0.0024	0.0028	0.0031	0.0028	0.0011	0.001
As	0.0011	0.001	0.0011	0.001	0.001	0.0015	0.001	0.0014	0.001	0.0011
N	0.0059	0.0046	0.006	0.002	0.0025	0.002	0.002	0.002	0.0053	0.2
Se	0.0029	0.0032	0.0029	0.0018	0.0015	0.002	0.0013	0.0027	0.0022	0.001
Sb	0.001	0.001	0.001	0.0011	0.003	0.0065	0.0038	0.0063	0.0059	0.0066
Ta	0.005	0.005	0.005	0.0187	0.0245	0.0245	0.0316	0.0255	0.0181	0.0109
CE	0.34	0.33	0.33	0.34	0.44	0.43	0.43	0.43	0.49	0.46

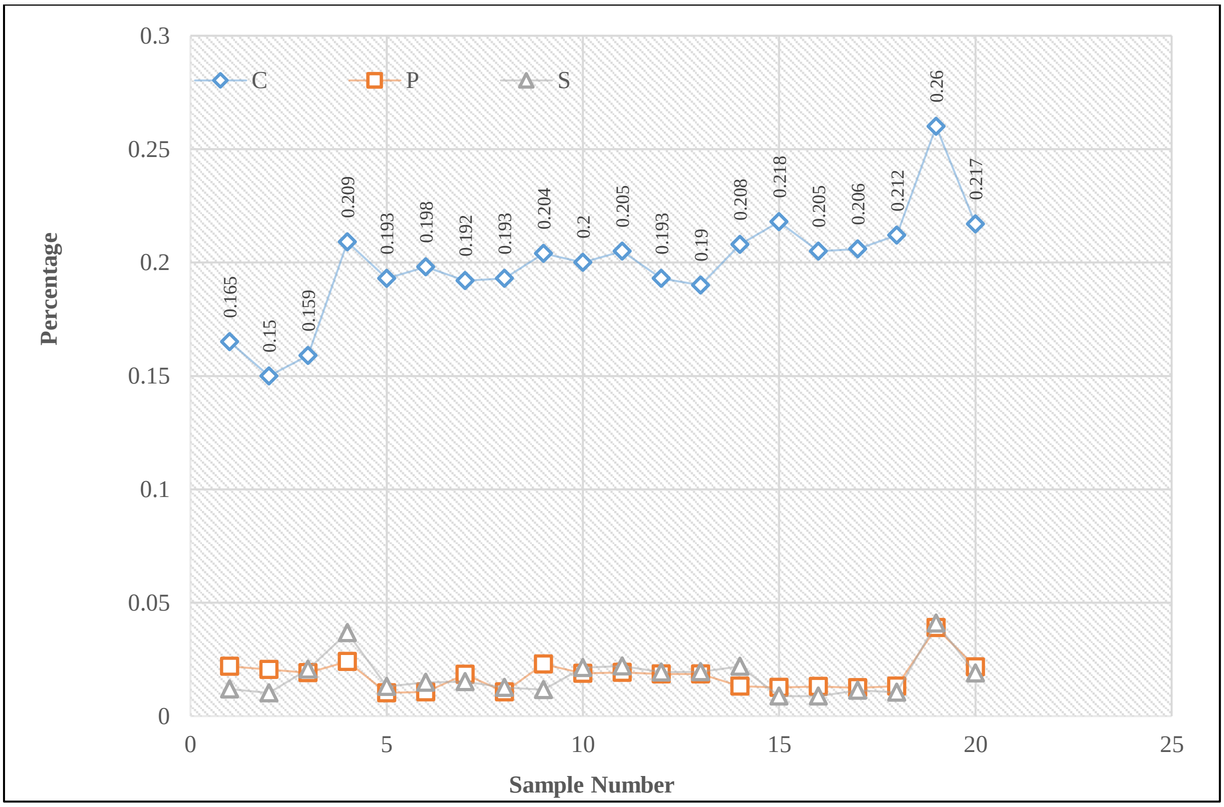

Fig. 2 The figure represents the sample number and the corresponding percentage of carbon, phosphorus and sulphur

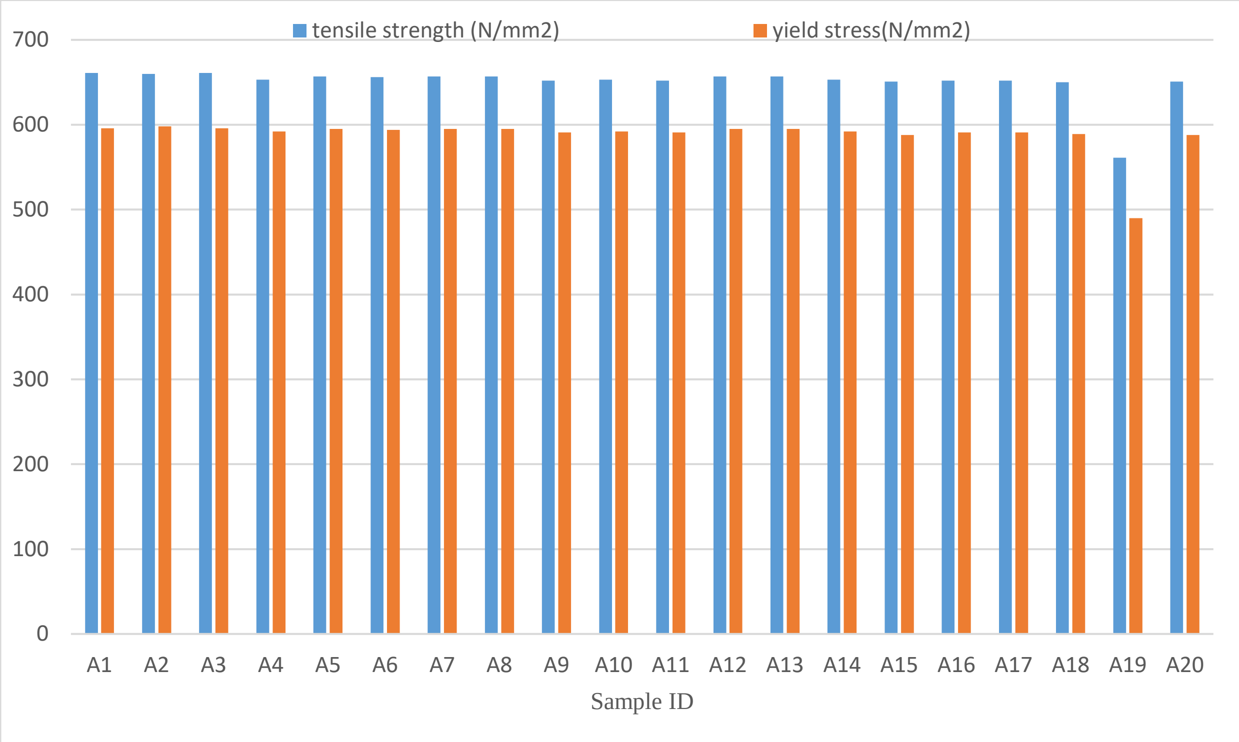

Fig. 3 Comparison of tensile strength and yield strength

Fig. 4 The graph represents the CE values for respective samples.

V. CONCLUSION

The results for chemical analysis over optical emission spectroscopy (OES), shows the concentration of the elements present in various samples and the respective samples tensile strength and yield stress in N/mm2 has reported. The results clearly mentions that the increase in carbon concentration decreases the yield stress and tensile stress. And the concentration of other elements such as sulphur and phosphorus too impact tensile strength and yield strength. Thus bar rods used in the construction and for other purposes should have less carbon percentage in it, in order to possess high tensile strength and yield strength.

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