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**Journal of Advanced Design**
*November 2025, Vol. 1, Issue 1*

Article

# An Experimental Study on the Ratio of Tensile Strength to Yield strength of two different grades of Reinforcing Bars

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## ABSTRACT

In order to study the effects of various tensile strength to yield strength ratios, if they are less or more than the required value, this article provides an overview of several steel grades, namely Grades 500 and 550 MPa.The assessment of recent research on the causes and effects of High TS/YS steel ratios has structural implications. Using high-strength steel bars offers several benefits, including a reduction in the reinforcement ratio, lower installation costs, reduced congestion from reinforcement, improved concrete placement, and an increase in service life due to enhanced resistance against corrosion. Despite being far stronger than standard reinforcing steel, high-strength reinforcing steel has a clearly defined yield point. Ductility is defined as the capacity of a structure, its elements, & its structural material to undergo inelastic deformations without losing its strength. Yield to tensile ratio serves as a measure of steel's ductility and ability to undergo strain hardening. Thanks to improvements in steel production techniques over time, motivated by the need to utilize stronger structural steels, it is now possible to produce steels with higher strengths that exhibit improved weldability, high toughness, and resistance to atmospheric corrosion.

**Key Words**: Mild Steel, Tensile Strength, Yield Strength, Elongation, Stress-Strain.

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## 1. INTRODUCTION

The substantial potential contribution of high-strength steels (YS>450 MPa) is yet largely untapped. This is mostly due to restrictions in codes, with the maximum allowed limit for the yield stress to ultimate stress ratio being particularly harsh.

The assessment of recent research on the causes, and the effects of High TS/YS steel ratios have structural implications. The three restrictions mentioned in the codal provision for the design of reinforced concrete are the yield strength value, the ratio of tensile strength to yield strength, and the elongation in steel bars used in concrete reinforcement. One of three limits based on the codal provision that should not be less than 1.06 is the ratio of tensile to yield strength. The criteria depend on the assumption that a structural member's capacity to induce inelastic rotation is influenced by the length of the yield area. For the design of strong and long-lasting concrete structures, steel reinforcement must be characterized just as concrete ingredients are categorized. The characterization of reinforcing bars is significantly influenced by the manufacturing process, the design specifications, and the building procedure. The mechanical properties and chemical composition including yield strength, ultimate strength, and elongation are frequently taken into consideration when describing reinforcing bars.

Numerous advantages of using high-strength steel bars include a reduction in the reinforcement ratio, lower installation costs, less congestion of reinforcement, better placement of concrete, and an increase in service life due to higher resistance against corrosion. The adoption of such high-strength steel presents several questions, including whether the reinforced concrete (RC) beam will be sufficiently ductile under ultimate load and whether the higher stresses generated in the steel under service load will lead to unacceptable large cracking and deflection.

High strength steel reinforcement differs significantly from typical Grade of steel reinforcement in terms of its stress-strain properties. Despite being far stronger than standard reinforcing steel, high-strength reinforcing steel has a clearly defined yield point.

Designing buildings to withstand the wrath of nature, including earthquakes, hurricanes, tornadoes, and snowstorms, has been challenging and occasionally unsuccessful.

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Understanding the nature and consequences of such natural threats as well as the requirements of a structure are essential for developing an effective structural design. Structures are designed to be safe and useful during normal use and occupancy, and at the very least, to be protected from collapsing during extreme events, such as earthquakes.

If the structures and members are robust and stable enough to ensure that the effects of the factored loads acting in the most significant combination are either more than or equal to the factored resistance, safety is guaranteed.

To prevent widespread collapse due to local failure, the analysis of structural components and their connections must provide sufficient structural strength. Serviceability of the structure is ensured by balancing the structural components and frames. By doing this, you can ensure that the serviceability traits—such as deflection and vibration—are within permissible ranges for both the type of materials supported and the expected use and occupancy.

To minimize collapse during catastrophic events like earthquakes and maximize economic efficiency, structures must be ductile. Ductility is defined as the capacity of a structure, its elements, and the structural material to undergo inelastic deformations without losing strength.

Structural steel is one of the most ductile materials used in contemporary structural engineering. Beginning in the early 20th century, structural steel consisting of mild carbon with a minimum yield stress Fy of 190 MPa to 225 MPa was used to construct buildings and bridges in North America. With a permissible yield to tensile strength ratio of 0.5 and a specified tensile strength range of 380 to 450 MPa, the yield strength Fy/Fu was met. The yield-to-tensile ratio measures the ductility and ability of steel to undergo strain hardening. Thanks to improvements in steel production techniques over time, which were motivated by the need to use stronger structural steels, steels of higher strength are now feasible, with increased weldability, high toughness, and improved atmospheric resistance against corrosion.

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## 2. RESEARCH BACKGROUND

Design factors make the reinforcing bars' strength, ductility, and corrosion resistance critical. Rebar's capacity to bend and weld is two essential qualities from the perspective of construction. The necessary ductility of the reinforcing bars could be ensured against all forms of loadings, including repetitive, monotonous, and loaded by elongation in reverse.

There are various ways to achieve a sufficient level of structural ductility, such as confining the structure of individual elements and utilizing reinforcing bars with lengthy elongations. Standards used for earthquake-resistant design should include a maximum yield strength restriction. Absence of such a restriction may cause the structure to fail in a brittle (shear) manner.

The standards outlined in IS 1786 for reinforcing bars of the Fe 415 grade are consistent with those of other nations for ductile design. However, this is untrue for bars of grade Fe 550 as per IS 1786. Because design philosophies ask for ductility of bars to permit for inelastic deformation of structural elements, rebar of grades greater than Fe 415, particularly Fe 550 grade, should be used with caution. A maximum yield strength restriction should be part of the standards used for the design of resistance against earthquake.

Absence of such a restriction could result in brittle failure (shear) these design scenarios include designing for earthquake resistance, designing for impact load, designing slabs and beams with adjustable support moments and loads, designing against gravity loads, etc. In India, TMT bars are currently used to build concrete structures. Design stress strain curves for TMT rebar are not provided by IS 456 or SP 16, respectively. It is incorrect to use the CTD bar design curve. The design stress-strain curve and the value of the yield strength of TMT bars should be released by BIS.

For the project of greater importance, a restriction on the coefficient of variation of yield strength of reinforcing bars is desired.

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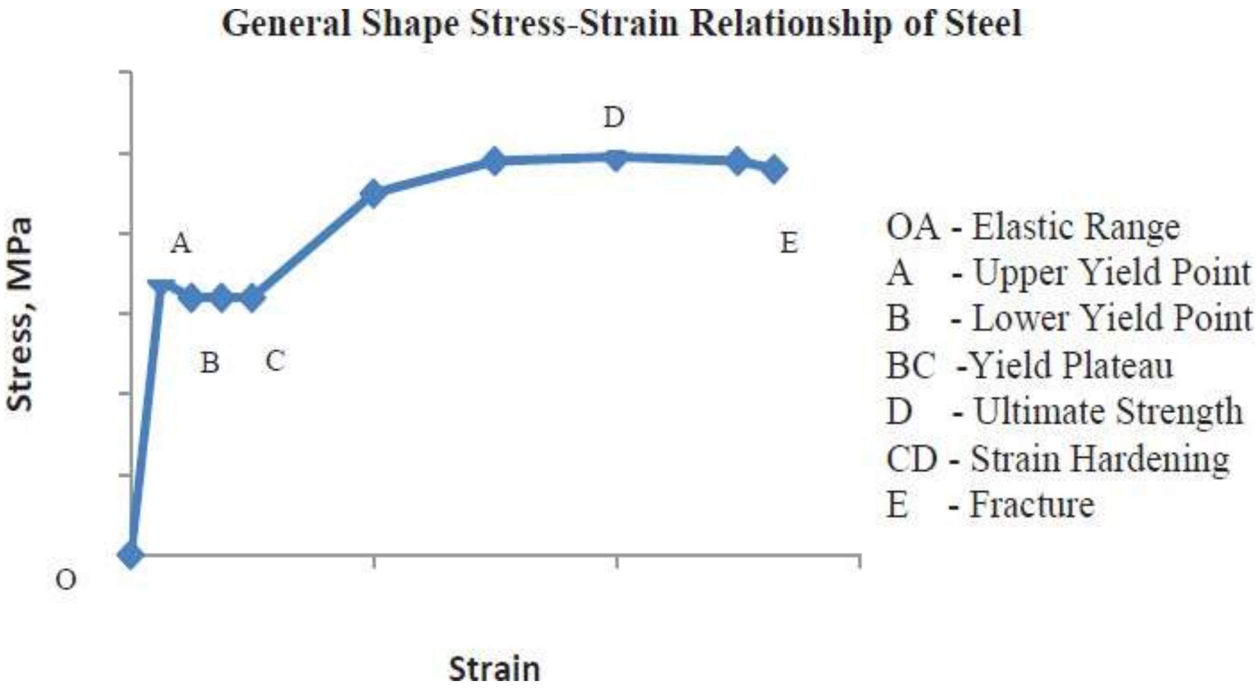

**Fig.-1** Stress-Strain curve for mild steel rebar

Stress-Strain curve of monotonically loaded (tension) mild steel rebar is shown in Fig.-1.

The above-mentioned curves exhibit an initial elastic zone, a yield plateau (i.e., a point beyond which strain increases with little to no increase in stress), a strain hardening region where stress increases again with strain, and finally a range of stress reduction until fracture occurs. The slope of the linear elastic portion of the curve corresponds to the modulus of elasticity of steel. The stress at the point of yield, commonly referred to as the yield strength, is a crucial component of steel reinforcement.

Reinforcement is frequently identified by its yield strength. It is believed that the stress-strain curves of steel in tension and compression are identical. On the stress-strain diagram for mild steel, there are two stress (yield) levels, which are designated as A and B in the Figure. A sudden decrease in tension can occasionally occur along with mild steel yielding. Points A and B represent upper and lower yield strengths, respectively. The location of the upper yield point depends on the test speed, the section's geometry, and the specimen's shape. The real feature of a material is often thought to be its yield strength, which for mild

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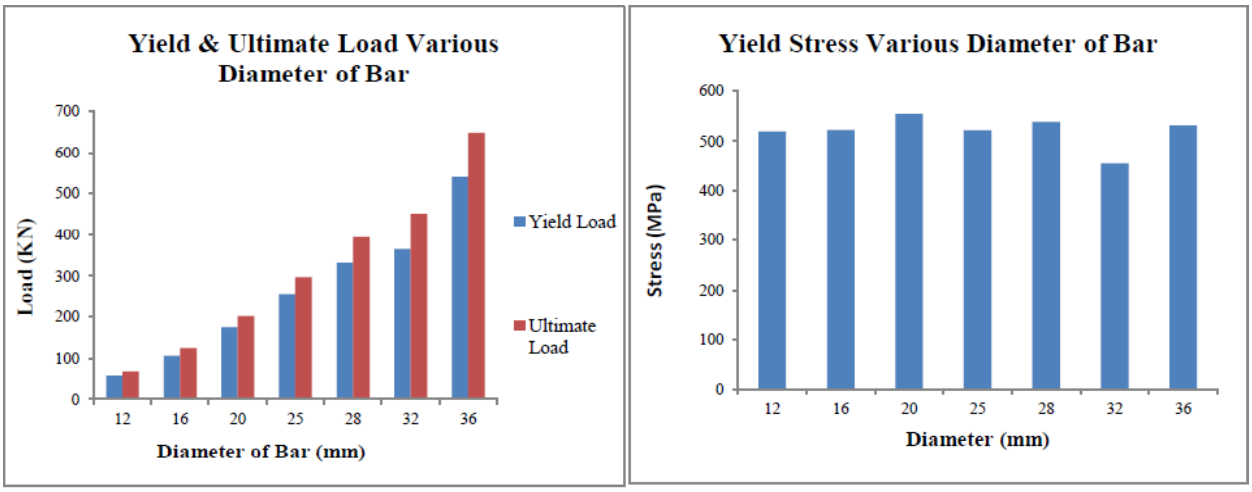
steel reinforcing bars is about 250 MPa.

The nominal diameters of the steel reinforcing bars, which ranged from 12 to 36 mm, were all made of 500 MPa grade steel. Tensile strength tests were performed on all reinforcing bars. One strain gauge was fastened to the surface of each size of the bar to measure the amount of strain experienced during the tensile test. According to the results of the tensile test, the bars were successful in achieving high strength values in each specimen with the exception of the 32 mm bars, which suddenly collapsed during the test.



(a) (b)

**Fig.- 2** (a) Yield and ultimate loads of various bar diameter

(b) Yield stress of various bar diameter

## 3. METHODOLOGY AND TESTING OF STEEL

Reinforcing bar steel was taken from lot available at construction site (sample length of 600mm) of different diameter available at site and of different grades. After collection of steel, steel was brought into the lab where testing was to be carried out.

For testing we took two grades of steel (Fe500, Fe550) and different dia of 8mm, 10mm, 12mm, 16mm, 20mm.

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### 3.1 Steps for sample preparation

1. Steel sample was taken and grade of steel, dia of steel was noted.
2. Length and weight of the sample was being taken and mentioned.
3. Gauge length was being marked w.r.t center of the steel sample

   Gauge length = 5*(dia of steel)
4. Sample is ready for testing.

**Fig.- 3 (a)** Deformed bar

**Fig.- 3 (b)** Steps in the testing of steel

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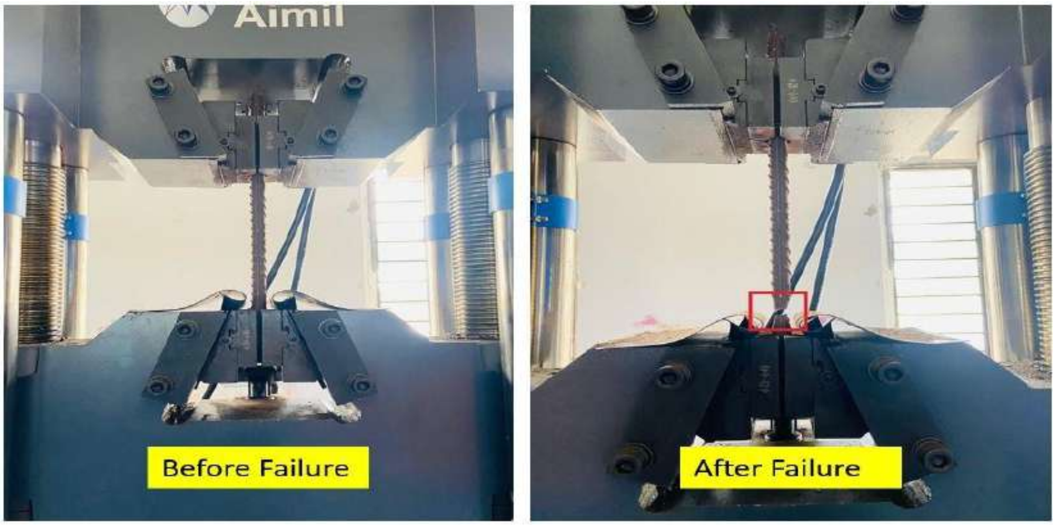
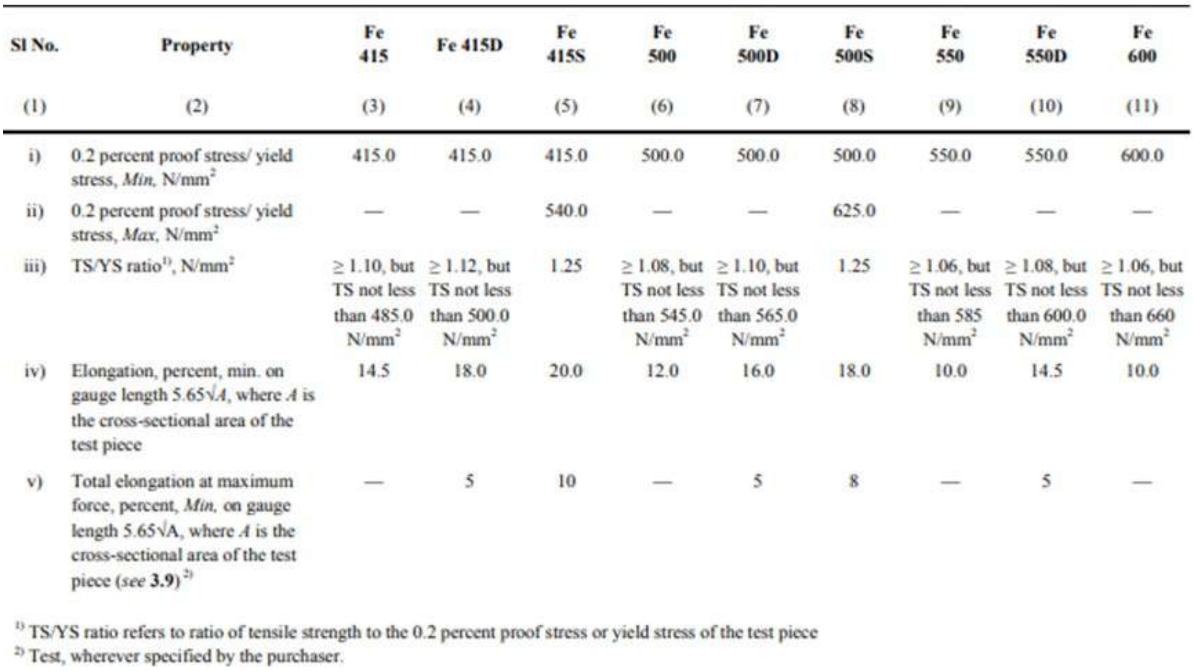


**Fig.- 3 (c)** steps for sample preparation

After sample is being prepared, the sample is put into UTM (Universal Testing Machine) for testing (For tensile test) and same procedure is followed for all the grades of sample and for all diameter of steel sample. After successfully conducting the testing of all the sample, data is collected and analyzed and data is reported in tabular form.

Table 3 : Mechanical Properties of High Strength Deformed Bars And Wires



| Sl No.<br>(1) | Property<br>(2) | Fe 415<br>(3) | Fe 415D<br>(4) | Fe 415S<br>(5) | Fe 500<br>(6) | Fe 500D<br>(7) | Fe 500S<br>(8) | Fe 550<br>(9) | Fe 550D<br>(10) | Fe 600<br>(11) |
|---|---|---|---|---|---|---|---|---|---|---|
| i) | 0.2 percent proof stress/ yield stress, *Min*, N/mm$^2$ | 415.0 | 415.0 | 415.0 | 500.0 | 500.0 | 500.0 | 550.0 | 550.0 | 600.0 |
| ii) | 0.2 percent proof stress/ yield stress, *Max*, N/mm$^2$ | — | — | 540.0 | — | — | 625.0 | — | — | — |
| iii) | TS/YS ratio[1], N/mm$^2$ | ≥ 1.10, but TS not less than 485.0 N/mm$^2$ | ≥ 1.12, but TS not less than 500.0 N/mm$^2$ | 1.25 | ≥ 1.08, but TS not less than 545.0 N/mm$^2$ | ≥ 1.10, but TS not less than 565.0 N/mm$^2$ | 1.25 | ≥ 1.06, but TS not less than 585 N/mm$^2$ | ≥ 1.08, but TS not less than 600.0 N/mm$^2$ | ≥ 1.06, but TS not less than 660 N/mm$^2$ |
| iv) | Elongation, percent, min. on gauge length $5.65\sqrt{A}$, where $A$ is the cross-sectional area of the test piece | 14.5 | 18.0 | 20.0 | 12.0 | 16.0 | 18.0 | 10.0 | 14.5 | 10.0 |
| v) | Total elongation at maximum force, percent, *Min*, on gauge length $5.65\sqrt{A}$, where $A$ is the cross-sectional area of the test piece (*see* **3.9**)[2] | — | 5 | 10 | — | 5 | 8 | — | 5 | — |

[1] TS/YS ratio refers to ratio of tensile strength to the 0.2 percent proof stress or yield stress of the test piece

[2] Test, wherever specified by the purchaser.

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**Fig.- 4** Table 3 from **IS 1786:2008** depicting standard values

The data obtained from the analysis was compared with the standard result mentioned in the IS code IS.1786:2008 (table 3) which is mentioned in the above figure.

The values which were compared were TS/YS ratio, Elongation, TS, etc.

## 4. RESULT AND DISCUSSION

The result obtained from the testing of all the samples are mentioned in the tabular form below.

| Grade | Bar Dia (mm) | Tensile Strength (MPa) | Yield Strength (MPa) | Weight (kg) | Ratio TS/YS | Elongation (mm) |
|---|---|---|---|---|---|---|
| Fe500 | 8 | 858.15 | 709.331 | 0.228 | 1.21 | 3 |
| | 10 | 669.79 | 446.305 | 0.31 | 1.50 | 10 |
| | 12 | 687.07 | 521.289 | 0.445 | 1.31 | 9 |
| | 16 | 507.78 | 376.969 | 0.948 | 1.35 | 11.5 |
| | 20 | 671.06 | 564.82 | 1.018 | 1.19 | 21 |

Table-1 Analysis of data of Fe-500 grade of steel

Comparing the obtained result with the standard result we can see that except for grade Fe500 (dia 16mm) all other sample passed the criteria and the lot from which the sample was being taken can be used for construction and the 16mm dia of steel is rejected. Stress-strain graphs of different diameter of steel obtained during tensile testing are mentioned below.

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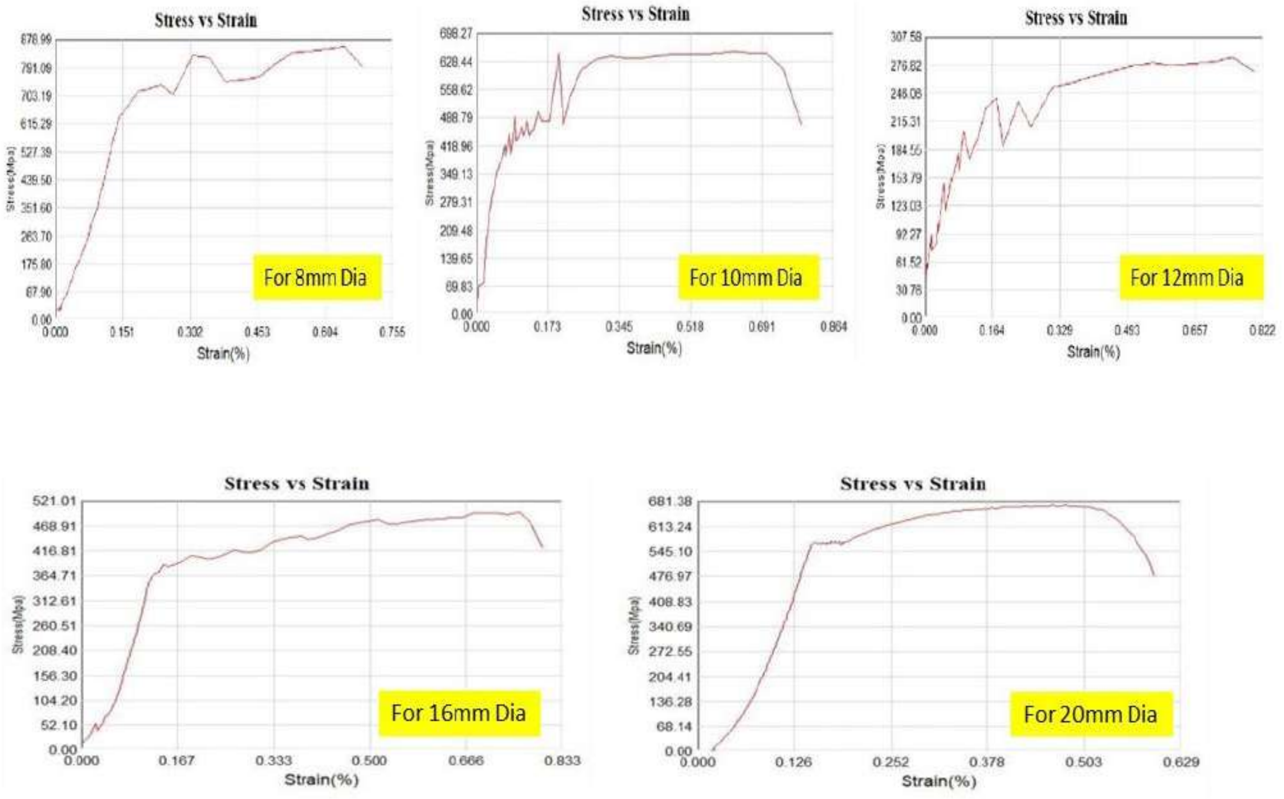

**Fig.- 5** Stress-Strain Diagram for different Dia of Grade Fe-500

The result obtained from the testing of all the samples are mentioned below in the tabular form below.

| Grade | Bar Dia (mm) | Tensile Strength (MPa) | Yield Strength (MPa) | Weight (kg) | Ratio TS/YS | Elongation (mm) |
|---|---|---|---|---|---|---|
| Fe550 | 8 | 773.82 | 592.213 | 0.25 | 1.31 | 8 |
| | 10 | 886.78 | 755.613 | 0.394 | 1.17 | 4 |
| | 12 | 474.13 | 379.733 | 0.552 | 1.25 | 12 |
| | 16 | 681.22 | 543.596 | 0.965 | 1.25 | 20 |
| | 20 | 664.65 | 543.477 | 1.490 | 1.22 | 22 |

Table-2 Analysis of data of Fe-550 grade of steel

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Comparing the obtained result with the standard result we can see that except for grade Fe550 (dia 16mm) all other sample passed the criteria and the lot from which the sample was being taken can be used for construction and the 12mm dia of steel is rejected. Stress-strain graphs of different diameter of steel obtained during tensile testing are mentioned below.

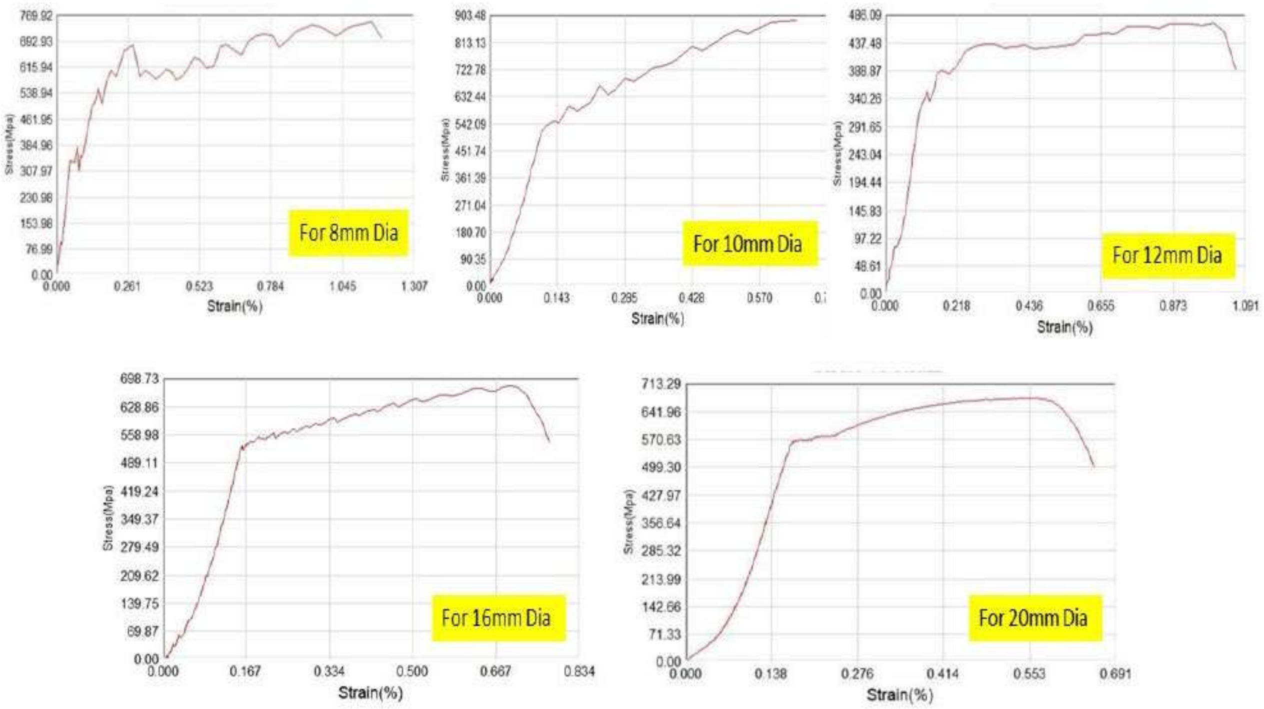

**Fig.- 6** Stress-Strain Graphs for Different Dia of Grade Fe-550

As we can see some of the steel sample from the lot got failed and because of that we will have to reject that steel so, there are only two way left for that steel, either we sell that steel in scrap which will reduce its value by one-third or it can be send back to the plant for remoulding, Either way we will have to incur huge loss and to avoid that loss to a minimum level we can make use of this steel only either by modifying some of the properties or by using it as an alternative of some other grade and dia of the steel. The steel sample which was rejected during the testing (Fe 500, 16mm dia & Fe 550, 12mm dia) will be further analyzed on the basis of their properties and will be compared with the lower grade and lower dia of steel in order to use those steel.

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## 5. CONCLUSION

All the testing mentioned above was done with the help of the UTM (Universal Testing Machine) with a load capacity of 1000KN, which is applied with a hydrostatically lubricated ram, and other assemblies.

The tensile test that we did can be concluded as:

**(1)** This paper states that the ratio of tensile strength to yield strength, also known as the elongation ratio, can vary depending on the grade of the reinforcing bar.

**(2)** Generally, higher grade of reinforcing bars tends to have a higher tensile strength to yield strength ratio, but in our case, there is no such fixed relationship.

**(3)** When selecting the reinforcing bars for a particular application, it is important to find the ratio of tensile strength to yield strength in order for their best utilization.

**(4)** The structure having a higher ratio of tensile strength to yield strength is said to have superior ductility.

**(5)** Upon further investigation of failed steel, we can use those steels with properties that match those of the other smaller grades of steel.

## 6. REFERENCES

1. Stress-Strain Relationship of High-Strength Steel (HSS) Reinforcing Bars, Retno Anggraini, Tavio, I. Gede Putu Raka & Agustiar (2018) https://doi.org/10.1063/1.5038307
2. ACI ITG-6R-10, "Design Guide for the Use of ASTM A1035/A1035M Grade 100 (690) Steel Bars for Structural Concrete", American Concrete Institute, Farmington Hill, MI, (2010),
3. Role of yield-to-tensile strength ratio in the design of Steel structures K.s.sivakumaran Professor, department of civil engineering, McMaster university, Hamilton, Ontario, l8s 4l7, Canada (2010)
4. Sooi, T.K., Green, P.S., Sause, R. And Ricles, J.M., (1995), Stress-Strain Properties of High-Performance Steel and the Implication for Civil-Structure Design, Proceedings of

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the International Symposium on High Performance Steels for Structural Applications, Cleveland, Ohio, USA

5. Tensile strength/yield strength (TS/YS) ratios Of high-strength steel (HSS) reinforcing bars Cite as: AIP Conference Proceedings 1964, 020036 (2018); https://doi.org/10.1063/1.5038318 Published Online: 15 May 2018 Tavio, Retno Anggraini, I. Gede Putu Raka, et al
6. Stress–strain curves and mechanical properties of corrosion damaged super ductile reinforcing steel Faraz Tariq (*GLA University Mathura, India*), Pradeep Bhargava (*IIT Roorkee, India)*
7. Indian Standard Specification for High Strength Deformed Steel Bars and Wires for Concrete Reinforcement. 1985, Bureau of Indian Standards New Delhi, India.
8. ASTM, C., 234-71: Standard Test Method for Comparing Concretes on the Basis of Bond Developed; 1 with Reinforcing Steel. Annual Book of ASTM Standards, Part, 1991; 14:173–179.
9. (ASTM A370-16, "Standard Test Methods and Definitions for Mechanical Testing of steel Products, American Standard Testing Material, International, West Conshohocken, PA, (2016).
10. IS 1786: 2008 for high strength deformed steel bars and wires for concrete reinforcement

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