# BUREAU OF INDIAN STANDARDS ,GUWAHATI

मानकः पथप्रदर्शकः

# INDUSTRIAL TRAINING DEFENCE

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# PROJECT OBJECTIVE

- Determination of Measurement Uncertainity of Nominal Mass, Tensile Strength, Yield Stress, Rib area in IS -2062 and IS -1786 .

# SESSION PLAN

- Introduction & Objective
- Measurement Uncertainty (MU)
- Overview of IS 2062 & IS 1786 Standards
- Experimental Setup & Methodology
- IS 2062 Tests
- IS 1786 Tests
- Conclusions
- References

# WHAT IS MU?

**Measurement Uncertainty** is "a non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand" . The uncertainity of a result of a measurand is lack of exact knowledge of the value of measurement or the doubt about the validity of result of measurement.

**Why we evaluate uncertainity?**

**1.**Uncertainity of a result is a quantitaive indication of its quality.

2.Allows comparisons of results while interpreting data.

3.It can be a key part of method validation.

4.For improvement of procedures.

5.To allow valid measurements and results to be obtained.

# WHY MU?

- **Method Validation**: Helps identify major error sources (mass, yield load, rib height), guiding calibration and sampling improvements.

*Reasons of variability: cumulative effect of variations in number of factors that influences the measurements, e.g. equipment, method, competence of persons , environment etc.*

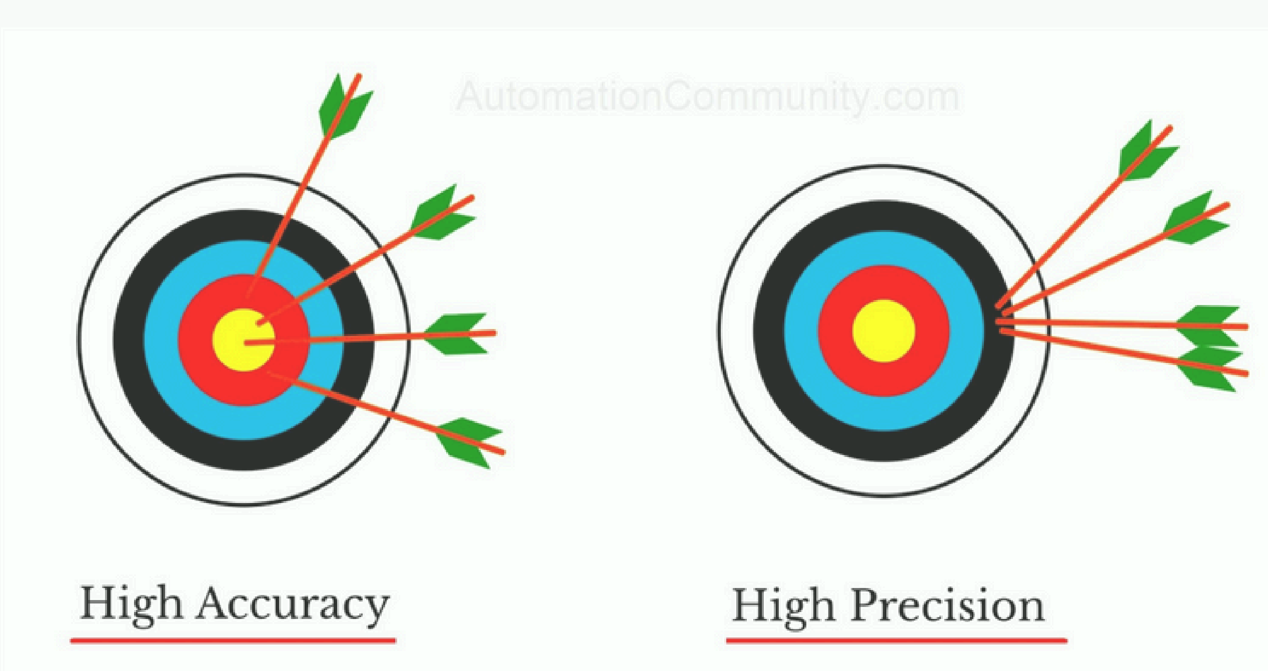
**Key Parameters & Their Uncertainties**

- Nominal Mass (W/L): From balance calibration (Type B) and length/dia repeatability (Type A).
- Tensile Strength & Yield Stress: Affected by UTM load-cell accuracy, gauge length, and area measurement.
- Stress Ratio : Depends on uncertainties in both yield and ultimate loads.
- Rib Area (IS 1786): Influenced by rib height/spacing measurement and twist pitch variation.

# IMP. TERMS

1. **True Value :** Value that is perfectly consistent with the definitions of given specific quantity
2. **Measurement:** Set of operations having the objective of determining a value of a quantity.
3. **Bias :** Diff. b/w measurement result and accepted reference value. Bias is the total systematic error. Ex-Error in calibration of a measurement equipment.
4. **Error:** The error is the diff. b/w TRUE value, X , and a MEASURED value, Xi.
5. **Precision:** It is measure of consistency (or repeatability).Maxm. deviation of reading from its mean value ( $max\,|X_{mean} - X_i|$).

Fig.-Visual Demonstration of Accuracy VS Precision

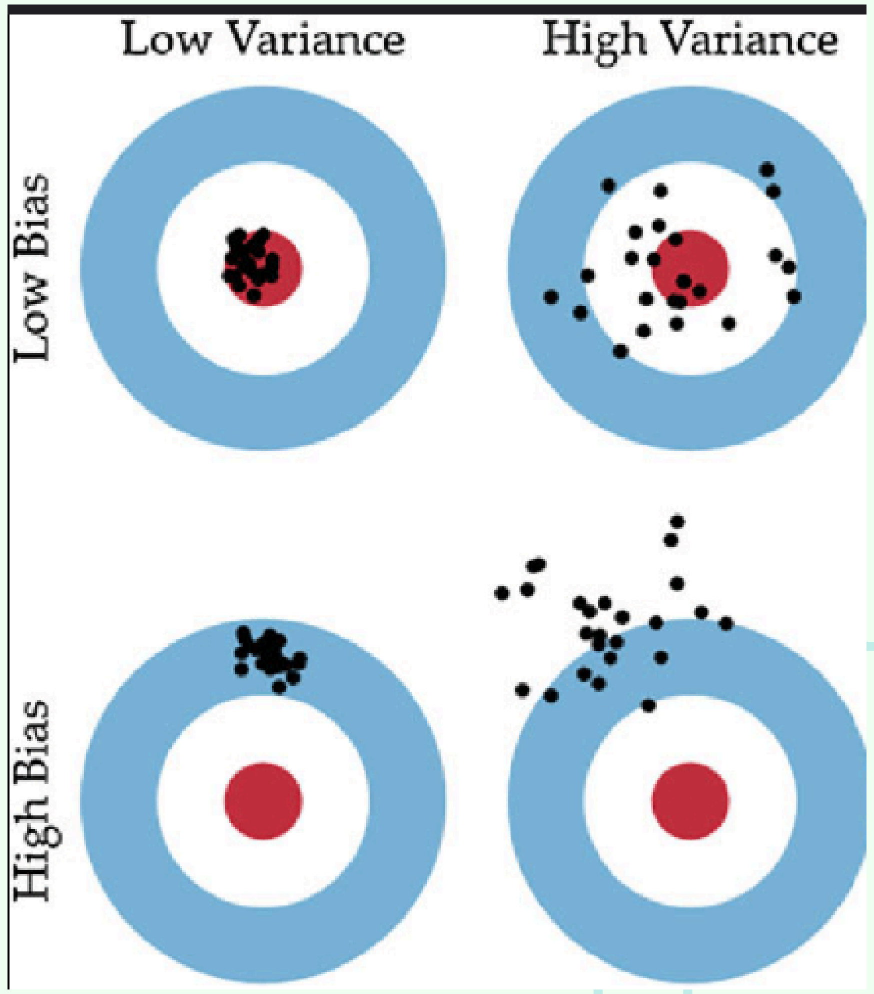


# IMP. TERMS

1. **Accuracy:** estimate of max|X-Xi|
2. **Random Error:** Result of a measurement minus the mean that would result from an infinite no. measurements of the same measurand carried out under repeatibilty conditions.
3. **Systematic Error: Error-Random Error**
4. **Variance**: A measure of dispersion, which is the sum of the squared deviations of observations from their average divided by one less that the no. of observations.
5. **Standard Deviations:** The positive square root of the variance.

$$s\left(q_j\right) = \sqrt{\frac{\sum_{j=1}^{n}\left(q_j - q_{mean}\right)^2}{n-1}}$$

$$Varience = \left(s\left(q_j\right)\right)^2$$



# IMP. TERMS

**Repeatability:**

Closeness of agreement b/w the results of successive measurements of same measurand carried out under repeatability conditions.

**The repeatabilty conditions are:**

- same measurement procedure.
- same observer.
- same measuring instrument, used under same conditions.
- same locations.
- repetition over a short period.

**Reproducibility:**

Closeness of agreement b/w the results of the measurement of same measurand carried out under changed conditions of measurement.

**A valid statement of reproducibility requires specification of conditions changes includes:**

- Principal of measurement
- method of measurement
- observer
- measuring instrument
- reference standard
- location
- time & condition of use.

# TYPES

1. **Type A Evaluation (Statistical Method)**

Type A uncertainty is evaluated using statistical analysis of repeated observations.

Use Case: When repeat measurements under same conditions are available.

Reference: NABL 141 Sec 3.3.2

**Formulas:**

- Mean (): $= \frac{1}{n} \sum x_n$
- Experimental Variance (): $s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_k - x_{mean})^2$
- Standard Uncertainty of Mean (): $\mu_a = \frac{s}{\sqrt{n}}$
- Degrees of Freedom (): $\nu = n - 1$

# TYPES

**2. Type B Evaluation (Non-Statistical/Judgment-Based)**

Type B uncertainty is evaluated using scientific judgment from:

- Calibration certificates
- Manufacturer specifications
- Resolution of equipment

Use Case: When data is not from repeated measurements.

Reference: NABL 141 Sec 3.3.3

Common Sources & Formulas:

- Calibration Certificate (95%): $\mu_B = \frac{U_{cert}}{k}$
- Manufacturer Tolerance: $\mu_B = \frac{Tolerence}{2}$
- Instrument Resolution (Rectangular Distribution): $\mu_B = \frac{a}{\sqrt{3}}$

$a = half\ least\ count$

# EXAMPLE

**Example ( Mass of a 1786-12 mm Bar)**

1. **Measured Data (Type A):**
   - Five repeated weighings of a 1 m length on a calibrated balance yield: 0.888 kg, 0.890 kg, 0.889 kg, 0.891 kg, 0.889 kg
   - Mean mass W=0.8894 kg
   - Experimental standard deviation s=0.0011 kg
   - Type A standard uncertainty= $\mu_a = \frac{s}{\sqrt{n}} = \frac{0.0011}{\sqrt{5}} = 0.00049kg$

2. **Instrument Resolution (Type B):**
   - Balance readability ±0.001 kg → assume rectangular distribution
   - Type B uncertainty $\mu_B = \frac{0.001}{\sqrt{3}} = 0.00058kg$

# EXAMPLE

**Combined Standard Uncertainty:** Total uncertainty from all sources (Type A and Type B), combined mathematically. It shows how much doubt exists in the final measured value.

$$Formula : \mu_c = \sqrt{(\mu_A)^2 + (\mu_B)^2}$$

.

**Expanded Uncertainty:** Expanded uncertainty is the range around your measured value that you're 95% confident the true value lies within.

It is calculated by multiplying the combined uncertainty u_c with a coverage factor k, which is usually 2 for 95% confidence.

$$U = k \times \mu_c$$

k=2 for 95% confidence (per NABL 141)

# OVERVIEW OF IS 2062 & IS 1786 STANDARDS

- IS 2062: Covers Hot rolled Medium and High Tensile structural steel.
- IS 1786: Covers High Strength Deformed Steel Bars (Concrete reinforcement).

- Key Requirements (for Testing & Reporting):
  - Nominal mass tolerances, sampling procedures.
  - Tensile and yield criteria (e.g., proof stress, elongation limits).
  - Rib geometry requirements (for HSD Bars).
  - Bend test guidelines.
- Why These Standards Matter:
  - Ensures steel quality, structural safety, predictable performance.

# OVERVIEW OF IS 2062 & IS 1786 STANDARDS

| Aspect | IS 2062 | IS 1786 |
|---|---|---|
| **Scope & Application** | Structural steel plates, strips, bars, flats, and sections (angles, beams, channels, I-sections) | Deformed (ribbed) steel bars (grades Fe 415 through Fe 600, with "D" variants requiring higher elongation as D-Enhanced Ductility) |
| **Grades & Designation** | Nine grades (E 250–E 650); sub-qualities A, BR, B0, C (specify impact-test levels and deoxidation method) | Four main grades—Fe 415, Fe 500, Fe 550, Fe 600—each with a "D" variant mandating higher elongation for improved ductility |
| **APPLICATION** | Bridges and Flyovers, Industrial and Power Plant Structure, Heavy Machinery, Storage Tanks and Pipelines, Railway Coaches and Wagons. | RCC Strucutres, Bridges and Flyovers, Seismic-Resistant Structure, Precast Concrete Elements, Infrastructure Projects. |

| Aspect | IS 2062 | IS 1786 |
|---|---|---|
| **Surface & Defect** | The finished material shall be reasonably free from surface flaws; laminations; rough/jagged and imperfect edges and all other harmful defects. | Surface must be sound and free from pipes or harmful defects; all bars must have longitudinal and transverse ribs per code |
| **Mechanical Testing** | Mandates tensile tests (IS 1608) for yield and ultimate strength on various sections also requires bend, impact, and other optional tests | Requires tensile tests (proof stress, yield point, ultimate stress) and total elongation on standard rebar specimens; mean rib area |
| **Nominal Mass & Tolerances** | Dimensional tolerances per IS 808 (sections), IS 1730/1732 (plates, bars); nominal mass calculated from section geometry; MU addressed | Nominal diameter/mass defined so that a plain round bar of the same mass equals the deformed bar's mass; tolerances governed by IS 1786/IS 1852 |

# METHODOLOGY

General Procedure (per IS Guidelines):

1. Sample selection & labeling- **IS 2062** (clause 9) **& IS 1786**
2. Dimensional measurement & mass measurement-for 2062 samples as per **IS 808** and **Tolerances** as per **IS 1852.**For HSD bares - **IS 1786**
3. **CSA** and **Gauge Length** calculation as per IS-2062 & 1786
4. Mounting samples on UTM for tensile/yield tests.
5. Rib area measurement (for HSD-1786).

# METHODOLOGY- IS 2062

- Material Grades & Sections **:-**Round bars , Square ,**angles , channels , I-sections**

**1.Location of Test Samples**:

– For bars (<28 mm), use as-rolled specimens without machining (CL-9.5).

– For angles, channels, I-sections, cut test pieces from recommended positions (flanges or web) to capture cross-sectional properties (CL- 9.1–9.3).

– Retain rolled surfaces on opposite faces where practicable (CL-9.2–9.4).

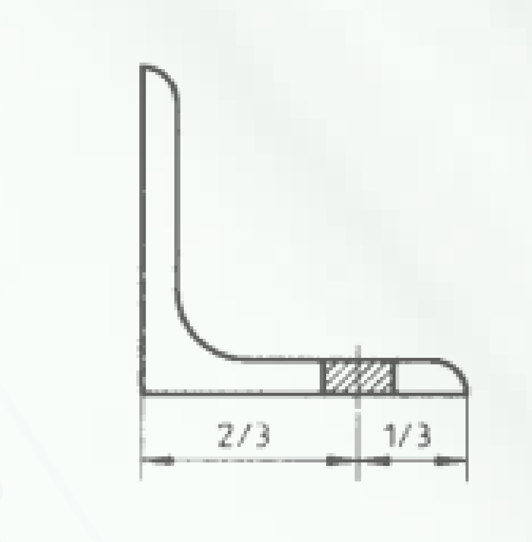



Fig.1

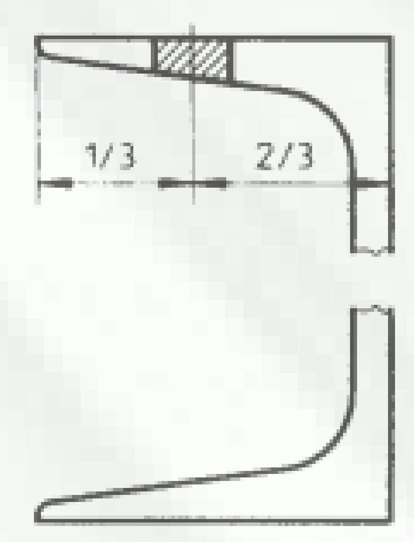



Fig.2

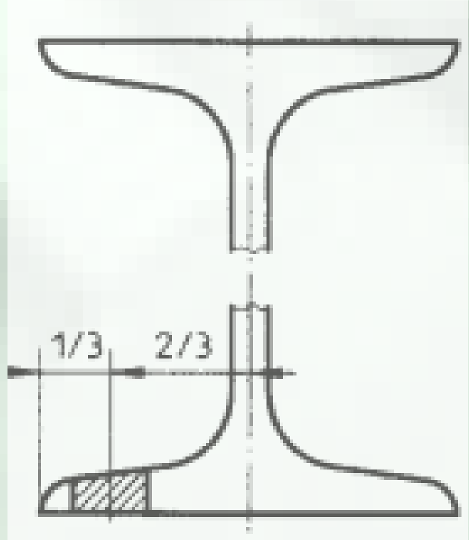



Fig.3

Source : IS 2062

## 2. Nominal Mass Measurement

- **Dimensional Measurement:** five equidistant locations along each bar/section.

- **Physical Mass Measurement**:
  – Measure the weight(**W**) of each sample on a calibrated balance (resolution ±0.1 g).
  – Record the exact length of each specimen (**L**, in meters) using a steel tape.
- **Nominal Mass Calculation (W/L):**
  – Compute linear mass density: $$m = \frac{W}{L}$$
  – Compute cross-sectional area from average dimensions:

$$\text{CSA}= \begin{cases} \frac{\pi d^2}{4} (round) \\ w \times t \, (rectangular sections) \end{cases}$$

Verify that CSA≈$\frac{m}{\rho}$ , $\rho$ =7850 kg/m3.

# 3. Gauge Length (GL)Determination (Clause 10.2.1)

- **Formula:** $$L_o = 5.65\sqrt{CSA}$$ $$L_o = GL$$

  (CSA in $mm^2$)

  ($L_o$ $in$ $mm$)

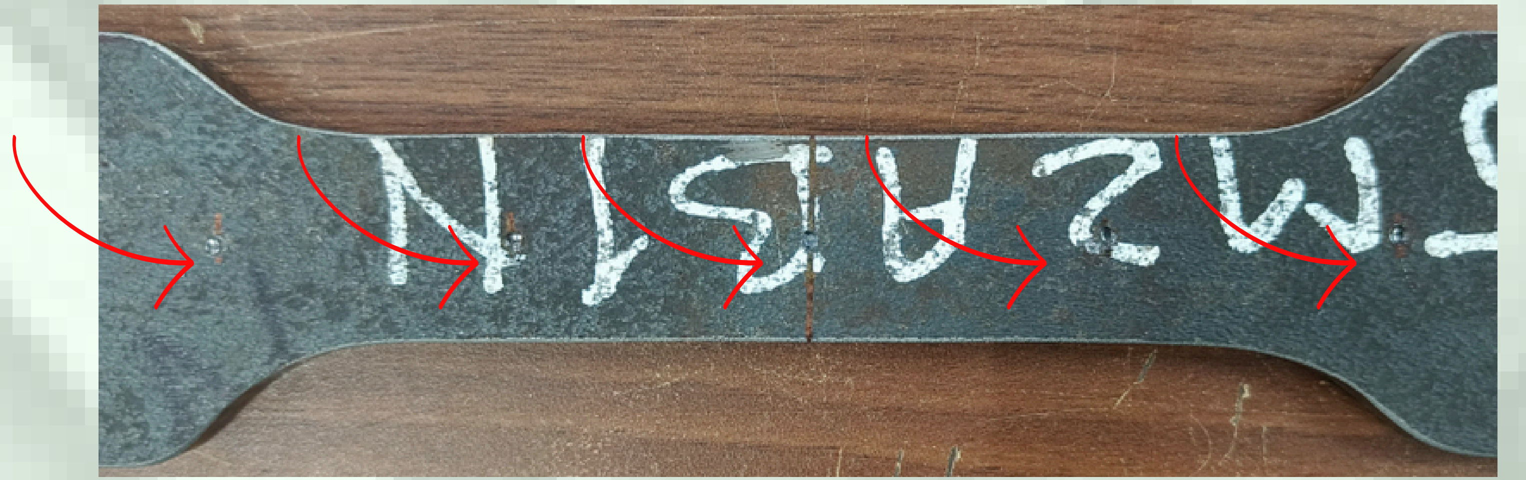
- **Procedure:**

  –Compute $L_o$ for each bar/section based on its measured CSA.

  – **Mark gauge length** (Lo) on the specimen surface - Punching on Testing sample (centred on the reduced section for tensile testing).

Note: GL to be rounded of to nearest integer and then punched.

Fig.4-Under Test sample , punched with GL =68 mm (source-Lab)



# 4. Tensile Testing (CL-10)

- **Specimen Preparation:**

1. Cut tensile test pieces crosswise from bars, angles, channels, and I-sections using minimal machining (10.2).
2. Maintain the rolled surface on at least two opposite faces (10.2).
3. For sections where thickness varies, apply the specified limits based on maximum thickness (10.3.1).

- **Testing Procedure (per IS 1608):**

1. Mount each specimen in the UTM with appropriate grips.
2. Apply tensile load at a constant rate until yielding and ultimate failure.

# 4.Tensile Testing (CL-10)

- **Data Reduction:**
  - Calculate yield stress Rp0.2= $\frac{F_{yield}}{CSA}$
  - Calculate tensile (ultimate) strength Rm= $\frac{F_{ultimate}}{CSA}$
  - Determine stress ratio $\frac{R_m}{R_p}$ .
  - Compute percentage elongation ε= $\frac{\Delta L}{L_o} \times 100\%$

    $where \Delta L = L_f - L_O$

$L_f \rightarrow$ Gauge Length after fracture

$L_o \rightarrow$ Initial Gauge length

Fig.-UTM-400KN sample under test

Fig.-Cup and Cone Formation

# 4. Data Collection & MU Estimation $MC150 \times 75 \times 6$

- **Parameters RecRecorded: IS 2062**

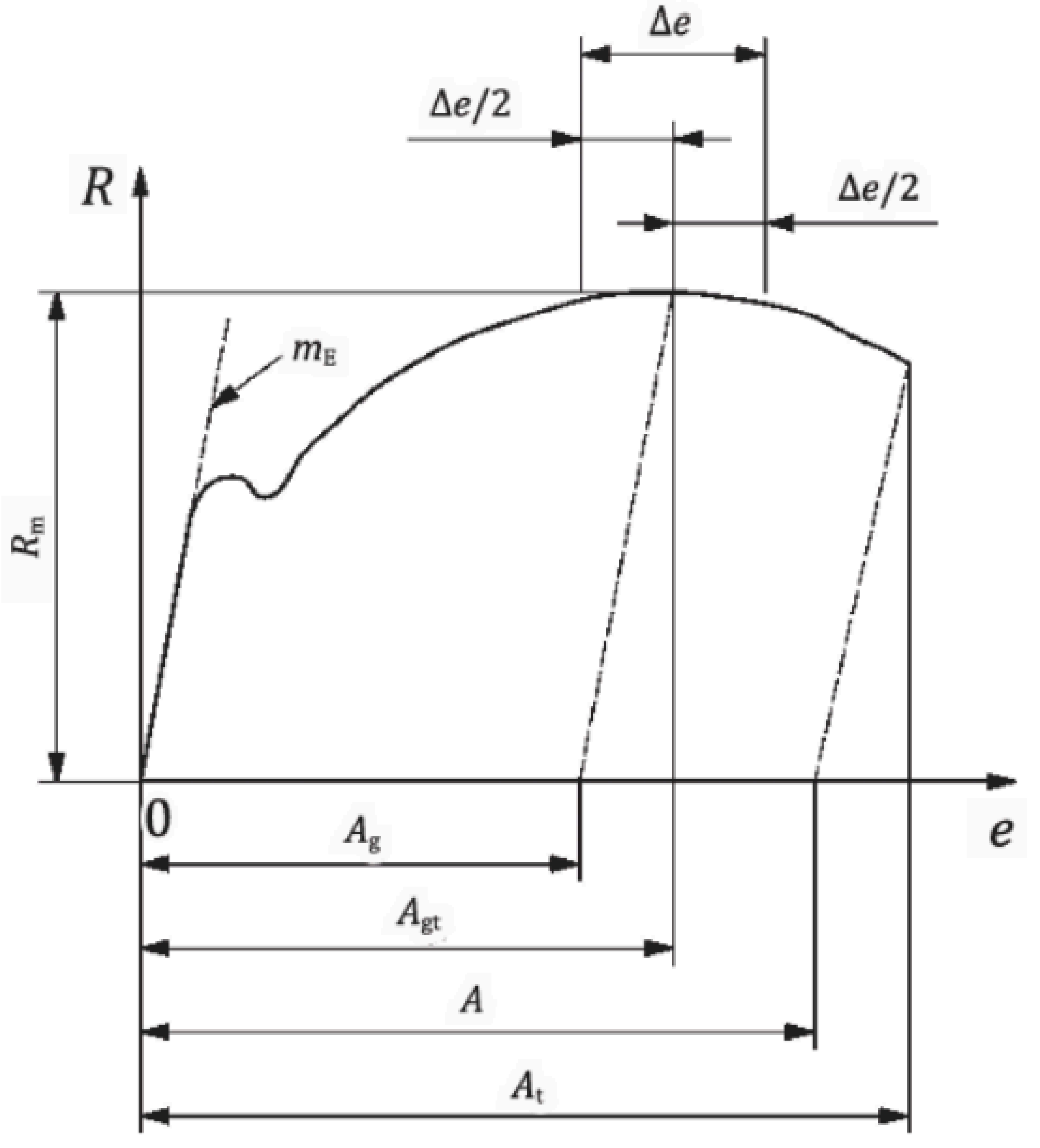
1. Nominal mass (linear density) for specimen $\frac{M}{L} = 17.067 \ \frac{Kg}{m}$
2. Measured CSA = 148.105 $mm^2$
3. Gauge length $L_o$ (calculated) = 69 mm
4. Yield strength = 282.666 MPa
5. Ultimate load = 366.128 MPa
6. Elongation = 27.145 %
7. Calculated yield stress, tensile strength, and stress ratio

$$\frac{Tensilestrenght}{Yieldstrength} = 1.295$$

| Grade Designation | Quality | Tensile Strength $R_m$, *Min* MPa[1] (*See* Note 1) | Yield Stress $R_{eH}$, *Min* MPa[1] | | | Percentage Elongation *A*, *Min* at Gauge Length, $L_o$=5.65 |
|---|---|---|---|---|---|---|
| | | | <20 | 20-40 | >40 | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| E 250 | A<br>BR<br>B0<br>C | 410 | 250 | 240 | 230 | 23 |

Fig.-Nominal Values IS 2062

# 4. Data Collection & MU Estimation $MC150 \times 75 \times 6$




Where ,

**A**: percentage elongation after fracture

**Ag**: percentage plastic extension at maximum force

**Agt**: percentage total extension at maximum force

**At**: percentage total extension at fracture

**e**: percentage extension

**mE**: slope of the elastic part of the stress-percentage extension curve

**R**: stress

**Rm:** tensile strength

**Δe:** plateau extent

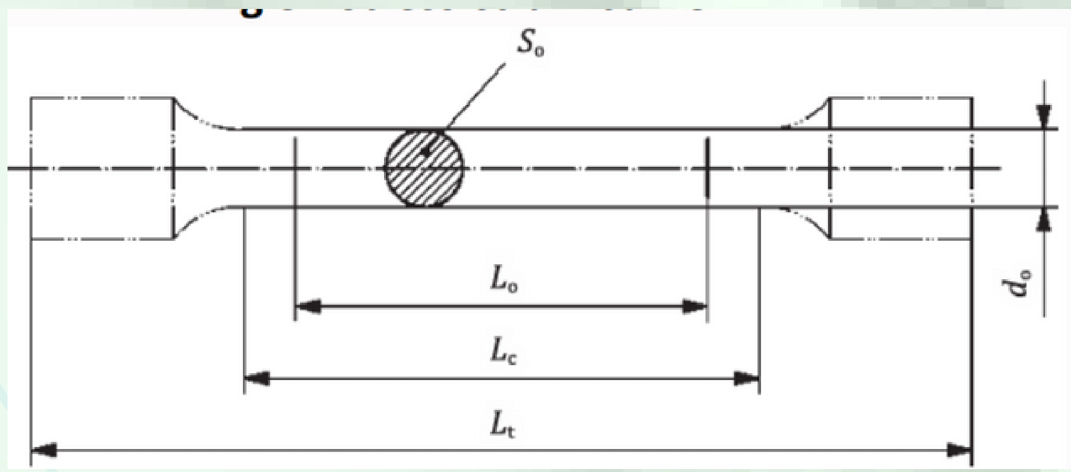



**Fig: Before Elongation**

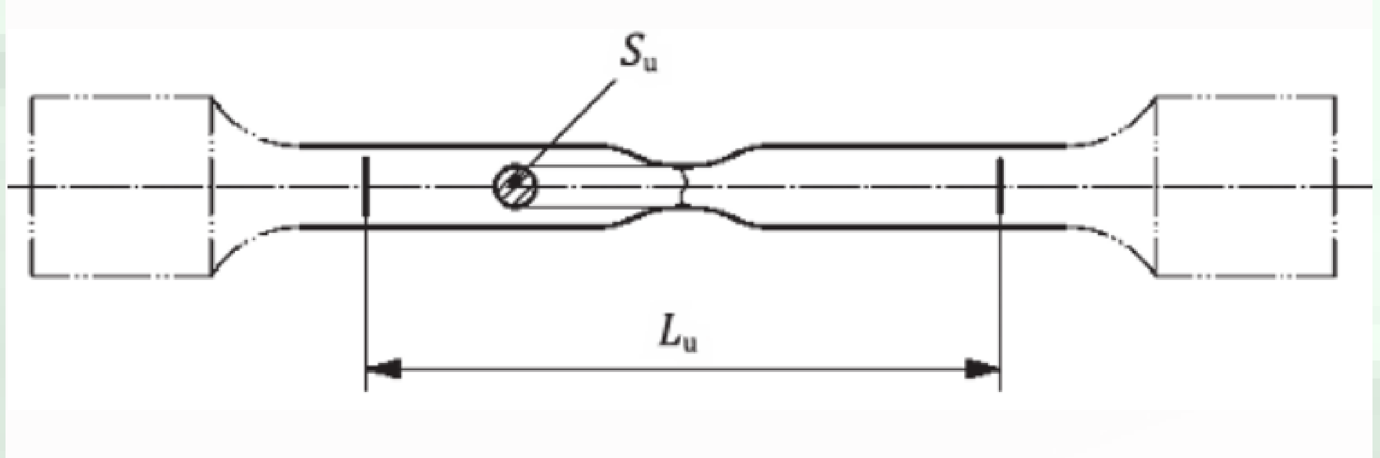
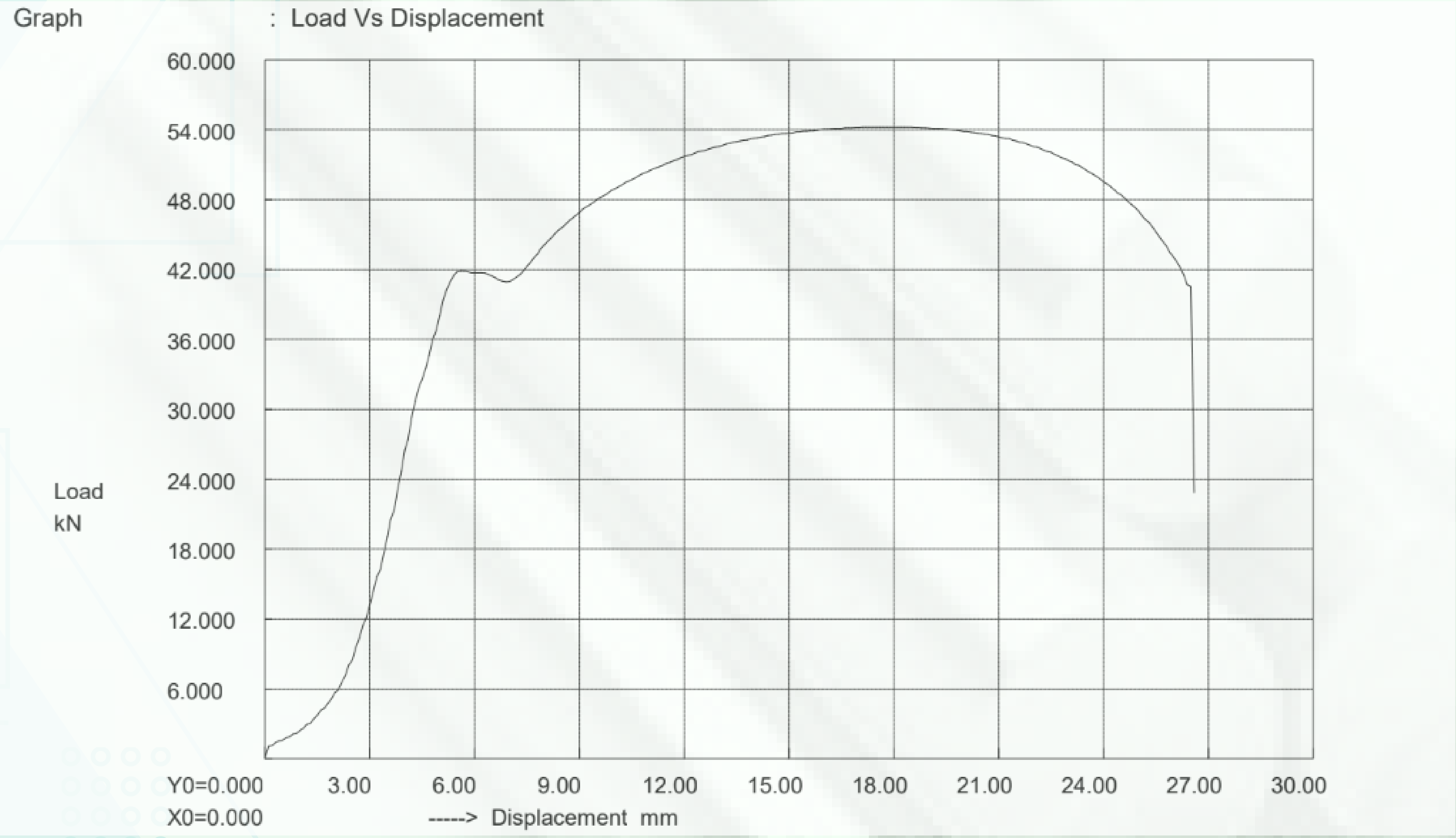



**Fig: After Elongation**

# 4. Data Collection & MU Estimation $MC150 \times 75 \times 6$




Test Report Graph -Load V/S Displacement

# METHODOLOGY- IS 1786

1. **Sample Selection & Preparation**

- **Bar Sizes Tested:** 8 mm, 10 mm, 12 mm, 16 mm, etc.
- **Sampling Guidelines** (as per IS 1786 Clause 6 & 7):
  – Sample length: Minimum of 1 m for nominal mass; longer for tensile tests (as per gauge length).
  – Ensure bar ends are cleanly cut without deformation.

2. **Nominal Mass and Cross Sectional Area Measurement** (Clause 6 & 7)

Gross Cross Sectional Area (in $mm^2$) $= \dfrac{w}{0.00785 \times l}$ $\quad (cl6.3.1)$

Nominal Mass (in $\frac{Kg}{m}$) $= 0.00785 \times (CSA)$ $\quad (cl7.2.1)$

**For bars of uniform cross sectional area**

# 2. Tensile & Yield Strength Testing (Clause 9.2)

**Determine yield stress (YS), tensile stress (TS), and percentage elongation of HSD bars**

**1.Gauge Length Marking:** L0 = $5.65 \times \sqrt{CSA}$ $(IS - 1608\,(CL8.1))$

Punch Gauge length on sample acc. to standard procedure.

**2.Tensile Test Procedure**

Equipment Used: Universal Testing Machine (UTM)

**Steps:**

1. Mount specimen in UTM grips.
2. Begin tensile test at constant strain rate.
3. Record: – Yield load
   – Ultimate load – maximum load sustained.
   – Elongation after fracture (ΔL).

# 3.Rib Area Calculation(Clauses 5.2 – 5.6)

**Mean Projected Rib Area per Unit Length ($A_r$)**
**(Clause 5.4 – Formula for transverse ribs)**

$$A_r = \sum_{i=1}^{n_t} \frac{A_{ti} \sin(\theta)}{S_t}$$

Where

$A_{ti}$ = longitudinal sectional area of i-th transverse rib

$\theta$ = inclination of rib to bar axis (°)

$S_t$ = transverse rib spacing (mm)

$n_{lr}, d_{lr}$ = number and height of longitudinal ribs

$\phi$ = nominal diameter (mm)

$$A_{ti} = \frac{2}{3} \times l_{tr} \times d_{tr}$$

- Rib Height & Spacing (Clause 5.5 & 5.6)
  - **Transverse Rib Height**: Measured at center of 10 successive ribs.
  - **Spacing (S):**Measured over 10 gaps between ribs → $S = \frac{Measuredlength}{Numberofspaces}$

# 3.Rib Area Calculation(Clauses 5.2 – 5.6)

**Deformation Limits for Bond Strength (Clause 5.2)**

Minimum projected rib area per unit length:

$$A_r = \begin{cases} 0.12 \times \phi \, (for \phi \leqslant 10mm) \\ 0.15 \times \phi \, (for 10 < \phi \leqslant 16mm) \\ 0.17 \times \phi \, (for \phi > 16mm) \end{cases}$$

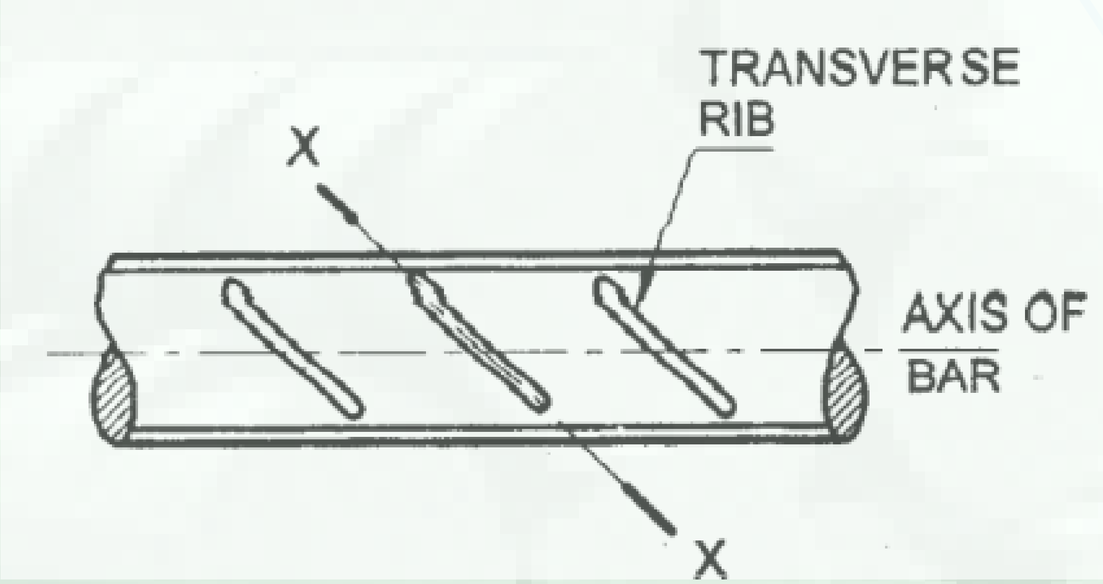



Fig. (a)

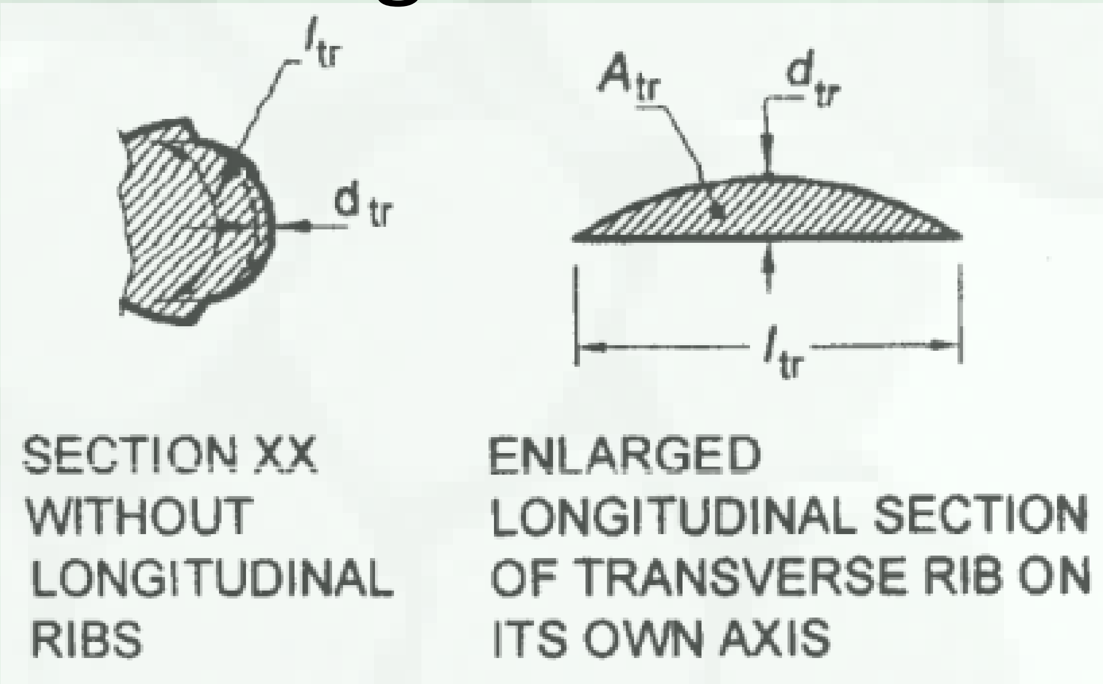



Fig. (b)

**Fig. (a) & (b) represents**—Ar,dtr and ltr represent longitudinal sectional area, height and length respectively of transverse rib

# 3.Rib Area Calculation(Parabola approximation)

The parbola formula assumes that the rib height, as function of distance along the circumference of the rebar , can be approximated by a second order curve.

Due to assumed symmetry only one quarter of the geometry needs to be solved ,and subsequently multiplied by 4 (*2 rib rows with 2 symmetrical half ribs per row).*

- If we denote the distance along the circumference by symbol s , and rib height as y(s), then we need to solve for the coefficient b in the general eqn. of parabola.
- $y(s) = -b.\, s^2 + a_m \quad --(1)$
- This is easily done by substituting value of zero rib height at s = $\frac{\pi d}{4}$

$$0 = -b.\left(\frac{\pi d}{4}\right)^2 + a_m \implies y = -a_m\left(\frac{4}{\pi d}\right)^2.\, s^2 + a_m \qquad (from 1)$$

Total projected rib area by $A_R$

$$\frac{A_R}{4} = \int_0^{\frac{\pi d}{4}} a_m\left(1 - \left(\frac{4}{\pi d}\right)^2.\, s^2\right) ds \implies A_R = 4a_m\left(s - \frac{1}{3}\left(\frac{4}{\pi d}\right)^2 s^3\right)_0^{\frac{\pi d}{4}} = 4a_m\left(\frac{\pi d}{4} - \frac{1}{3}.\,\frac{\pi d}{4}\right)$$

# 3.Rib Area Calculation

$$= \frac{2}{3} . a_m . (\pi d)$$

In the first figure X-axis represent Distance along circumference and Y-axis tells Rib Height.

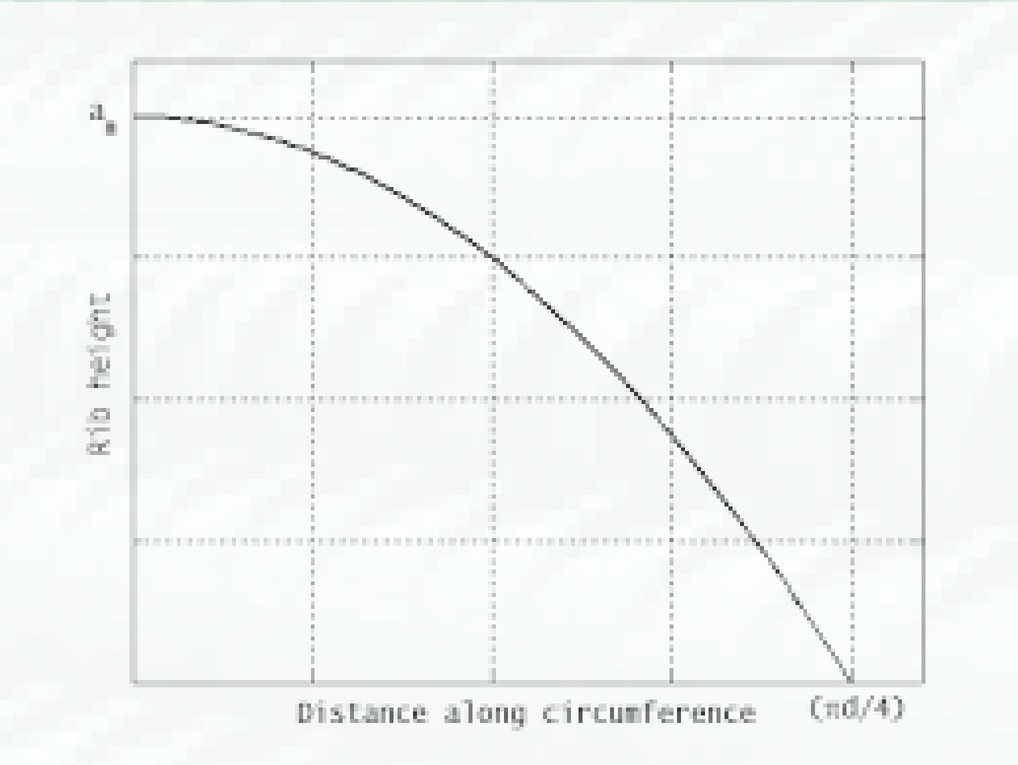



Fig.

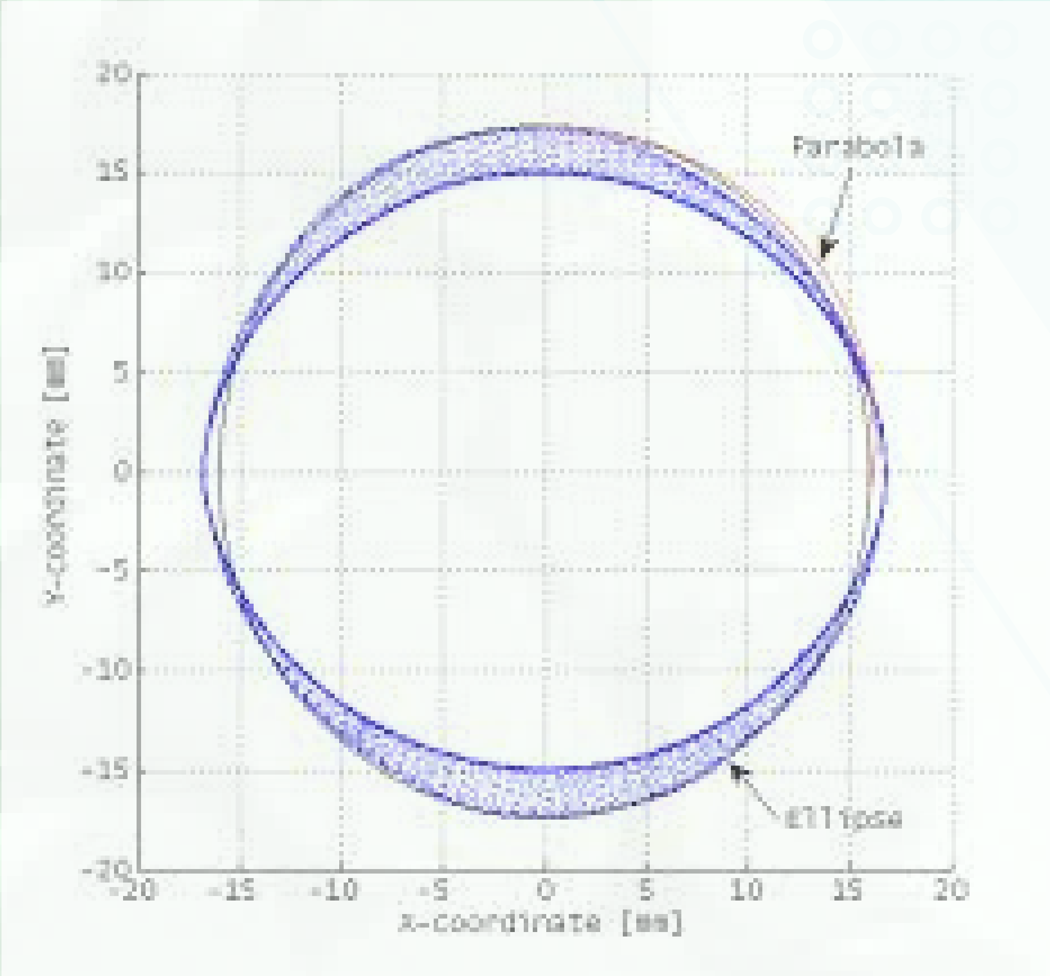



Fig.

(Parabolic Shape of rib height)

(***Source*** :Technical Paper by JP Jordan)

Procedure:

**1.**Take imprints of the rod rib pattern on the A4 sheet using.

**2.** Now mark 2 faces A and B for 2 faces of rod.Take imprints such that 2 faces can be differentiated easily.

# 3.Rib Area Calculation

**3.** Now measure the Rib angle, Length, Height , STR.

Note: For Str lenght should be taken such that it should be $\geqslant 10 \times \phi$

**4.**Now calculate the area using the formula for diff. ribs and find its sum. $\sum A_i$

**5.**Ensure that sum should satisfy the condition as mentioned.Take multiple readings of each parameter to get accurate results and to measure Uncertainity.

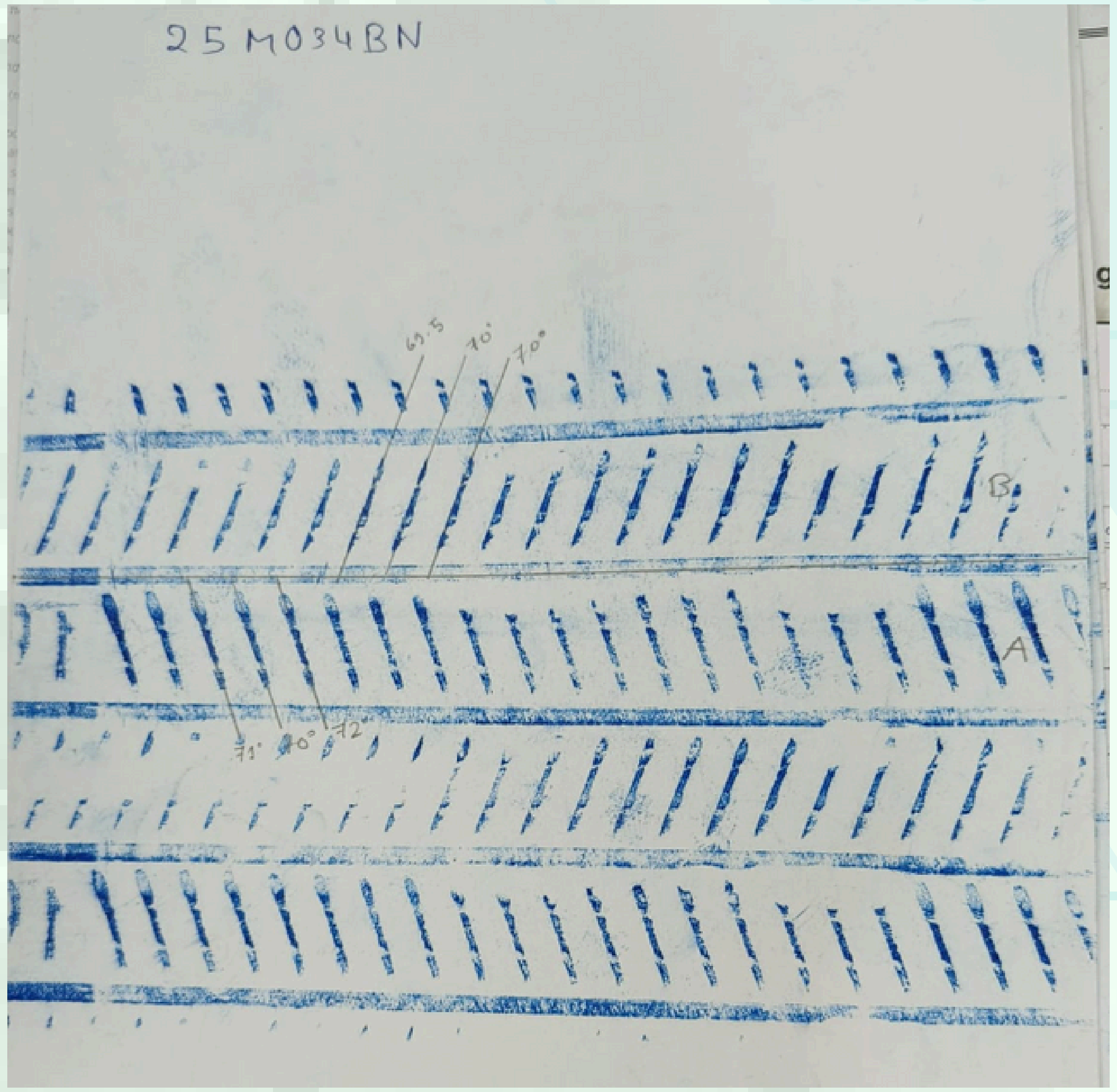



Fig.: Rib imprints

Example: Sample 16mm HSD Bar

- Taken imprints on A4 sheet with the help of carbon paper as shown in fig. on right.
- Calculate rib area with help of the formula.
- Check for the minimum projected area.

# Rib Area Calculation

## $Face - A$

$\theta_{avg.} = 71^o$ $\quad$ $d_{tr,avg.} = 1.262mm$

$l_{travg} = 26.11mm$

$S_{tr,avg} = \frac{169}{19}mm$

$$A_1 = \frac{2}{3} \times \frac{l_{tr} \times d_{tr} \times \sin(\theta)}{S_{tr}}$$

$\Rightarrow A_1 = 2.33513mm^2$

## $Face - B$

$\theta_{avg.} = 68.833^o$ $\quad$ $d_{tr,avg.} = 1.172mm$

$l_{travg} = 26.366mm$

$S_{tr,avg} = \frac{171}{19}mm$

$$A_2 = \frac{2}{3} \times \frac{l_{tr} \times d_{tr} \times \sin(\theta)}{S_{tr}}$$

$\Rightarrow A_2 = 2.13457mm^2$

Total Area=4.46965 $mm^2$ > 0.15 $\star \varnothing$=2.4 $mm^2$

# 4. Data Collection

- **Parameters Recorded: IS 1786** 16 mm HST bar Fe-500

1. Nominal mass (linear density) for specimen $\frac{M}{L} = 1.574 \ \frac{Kg}{m}$
2. Measured CSA = 223.284 $mm^2$
3. Gauge length $L_o$ (calculated) = 84 mm
4. Yield strength = 503.483 MPa
5. Ultimate load = 602.997 MPa
6. Elongation = 18.560 %
7. Calculated yield stress, tensile strength and stress ratio $\frac{R_m}{R_p} = 1.198$

**Table 3 Mechanical Properties of High Strength Deformed Bars and Wires**
(*Clause* 8.1)

| Sl No. (1) | Property (2) | Fe 415 (3) | Fe 415D (4) | Fe 415S (5) | Fe 500 (6) | Fe 500D (7) | Fe 500S (8) | Fe 550 (9) | Fe 550D (10) |
|---|---|---|---|---|---|---|---|---|---|
| i) | 0.2 percent proof stress/ yield stress, *Min*, N/mm² | 415.0 | 415.0 | 415.0 | 500.0 | 500.0 | 500.0 | 550.0 | 550.0 |
| ii) | 0.2 percent proof stress/ yield stress, *Max*, N/mm² | – | – | 540.0 | – | – | 650.0 | – | – |
| iii) | TS/YS ratio [1], N/mm² | ≥ 1.10 (butTS not less than 485 N/mm²) | ≥ 1.12 (but TS not less than 500 N/mm²) | ≥ 1.25 | ≥ 1.08 (but TS not less than 545 N/mm²) | ≥ 1.10 (but TS not less than 565 N/mm²) | ≥ 1.25 | ≥ 1.06 (but TS not less than 585 N/mm²) | ≥ 1.08 (but TS not less than 600 N/mm²) |
| 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 | 18.0 | 12.0 | 16.0 | 16.0 | 10.0 | 14.5 |

Fig.5-UTM-400KN sample

# 3.Data Collection

## Test Report

**TEST CERTIFICATE**

**Date : 29-05-2025 , 12:06 PM**

**Bureau Of Indian Standard (Guwahati)**

sample Identification : 25M034BN
Part description :
Part Number :
Machine : Universal Testing Machine 400 kN

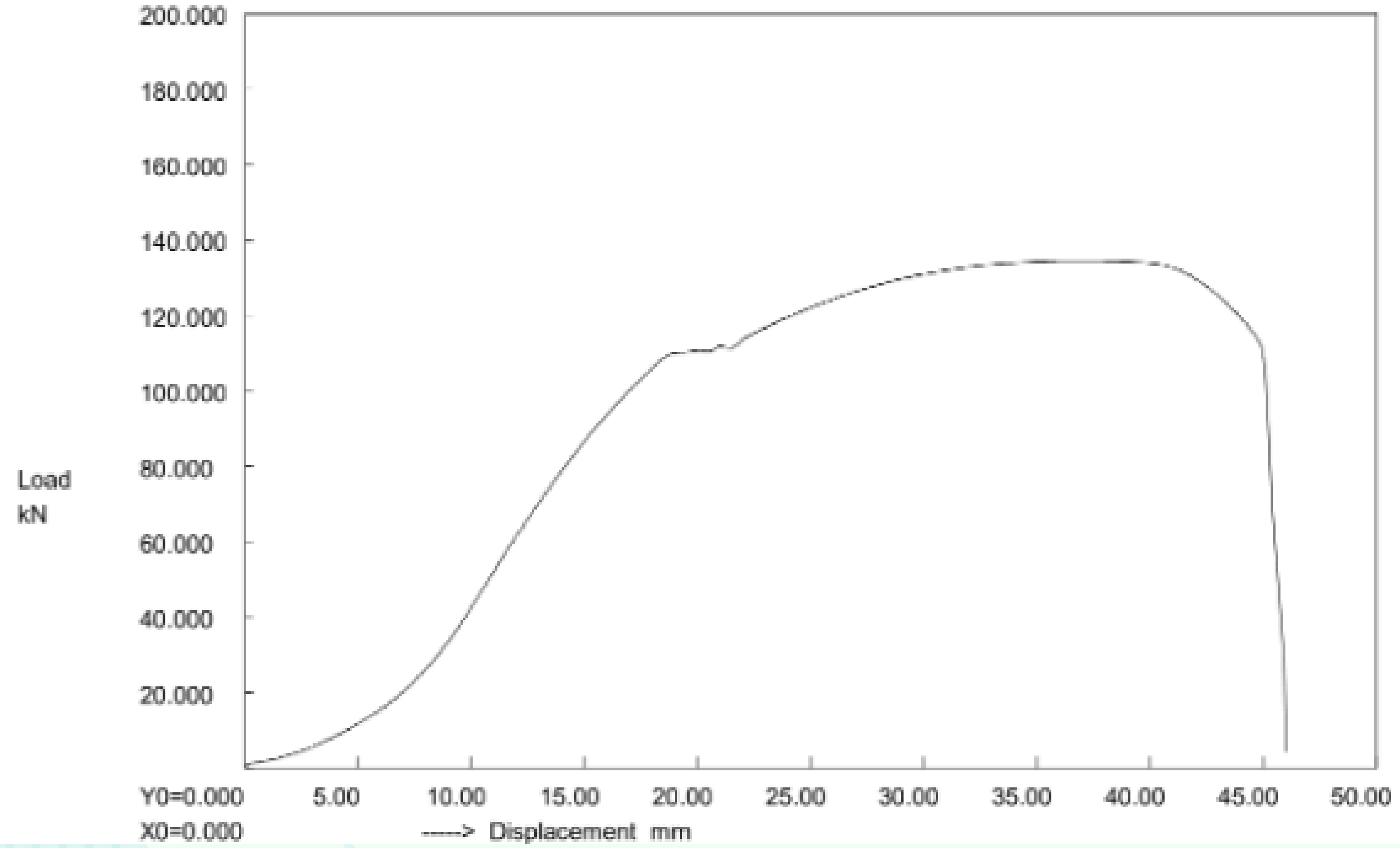
**Input Data**
File Name : 25M034BN , Record No. : 1
Sample Type : TMT , Area : 223.285 mm ²
Length : 898.0 mm Weight : 1.574 kg , Weight/meter : 1.753 kg
Gauge Length : 84 mm Final Gauge Length: 99.59 mm

**Results of Tension Test**

| | | | |
|---|---|---|---|
| Maximum Force (Fm) | : 134.640 kN | Elongation | : 18.560 % |
| Disp. at Fm | : 36.3 mm | Yield Load | : 112.420 kN |
| Max. Disp. | : 46.000 mm | Yield Strength (Re) | : 503.483 MPa |
| c/s Area (So) | : 223.285 mm ² | Stress Ratio Rm/Re | : 1.198 |
| Tensile strength (Rm) | : 602.997 MPa | | |

* Note : Yield Calculated from graph

Graph : Load Vs Displacement




# MU of Nominal Mass

## BUREAU OF INDIAN STANDARDS GUWAHATI LABORATORY

### UNCERTAINTY CALCULTAIONS

| | | | |
|---|---|---|---|
| **PRODUCT** | **HOT ROLLED MEDIUM AND HIGH TENSILE STRUCTURAL STEEL** | **Tested By:** | **Kartik Jaiswal** |
| **PRODUCT IS** | **2062** | **Temperature:** | **27±2° C** |
| **PARAMETER** | **NOMINAL MASS** | | |

**NOMINAL MASS = M/L M= MASS Kg L= LENGTH meters(m)**

**U(Nominal Mass)/Average(Nominal mass)=SQRT((u_Mass/Avg_Mass)^2 + (u_Length/Avg_Length)^2)**

**(A) Uncertainty in Length (L) estimation ( Type A):**

| S.NO. | Result (xi) | Mean (xm) | xi - xm | (xi - xm)2 | SD<br>√∑(xi - xm)2/n - 1 | Std. uncertainty<br>SD/√n | |
|---|---|---|---|---|---|---|---|
| 1 | 1.007 | | 0.0008 | 6.4E-07 | | | |
| 2 | 1.006 | | -0.0002 | 4E-08 | | | |
| 3 | 1.006 | 1.0062 | -0.0002 | 4E-08 | 0.000447214 | 0.0002 | m |
| 4 | 1.006 | | -0.0002 | 4E-08 | | | |
| 5 | 1.006 | | -0.0002 | 4E-08 | | | |
| | | | **∑(xi - xm)2=** | **8E-07** | | | |

**(B) Uncertainty in LENGTH (L) estimation ( Type B):**

| Equipment's | Declared MU | Declared Unit | At Factor K = | Least Count | Unit | Accuracy |
|---|---|---|---|---|---|---|
| **MEASURING TAPE** | 0.00028 | m | 2 | 0.001 | mm | NA |

# MU of Nominal Mass

| Sources of Uncertainty | Value | Type Of Disrtibution | Probability Distribution | Divisor | Divisor Value | Standard Uncertainty | Uncertainty Contribution U(y) ^2 | Degrees of freedom V | Sensitivity coefficient C i | |
|---|---|---|---|---|---|---|---|---|---|---|
| Repeatability of Length u(x1) | 0.000447214 | Type A | Normal | √n | 2.236067977 | 0.0002 | 4E-08 | 4 | -0.0001753 | mm |
| Uncertainty of Tape u(x2) | 0.00028 | Type B | Rectangular | 2 | 2 | 0.00014 | 1.96E-08 | ∞ | 1 | mm |
| Least count for Tape u(x3) | 0.001 | Type B | Rectangular | √3 | 1.732050808 | 0.00057735 | 3.33333E-07 | ∞ | 1 | mm |
| N= | M/L | | | | Combined Uncertainty (uL) = | | SQRT (u(x1)^2 + u(x2) ^2+u(x3)^2) | | | |
| c1= dx/dL= | -0.876497736 | cl*u1= | -0.0001753 | | | | 0.000626844 | m | | |

**(A) Uncertainty in Mass(M) estimation ( Type A):**

| S.NO. | Result (xi) | Mean (xm) | xi - xm | (xi - xm)2 | SD | Std. uncertainty | |
|---|---|---|---|---|---|---|---|
| | | | | | √∑(xi - xm)2/n - 1 | SD/√n | |
| 1 | 0.892 | | 0.0046 | 2.116E-05 | | | |
| 2 | 0.9 | | 0.0126 | 0.00015876 | | | |
| 3 | 0.888 | 0.8874 | 0.0006 | 3.6E-07 | 0.01485934 | 0.006645299 | Kg |
| 4 | 0.862 | | -0.0254 | 0.00064516 | | | |
| 5 | 0.895 | | 0.0076 | 5.776E-05 | | | |
| | | | ∑(xi - xm)2= | 0.0008832 | Kg^2 | | |

**(B) Uncertainty in Mass (M) estimation ( Type B):**

| Equipment's | Declared MU | Declared Unit | At Factor K = | Least Count | Unit | Accuracy |
|---|---|---|---|---|---|---|
| **Digital Balance 15 Kg** | 0.008 | Kg | 2 | 0.002 | kg | NA |

**Nominal Mass**

| S.NO. | Result (xi) | Mean (xm) | xi - xm | (xi - xm)2 | SD | Std. uncertainty | |
|---|---|---|---|---|---|---|---|
| | | | | | √∑(xi - xm)2/n - 1 | SD/√n | |
| 1 | 0.886503677 | | 0.004571656 | 2.09E-05 | | | |
| 2 | 0.894454383 | | 0.012522361 | 0.00015681 | | | |
| 3 | 0.882528324 | 0.881932021 | 0.000596303 | 3.55577E-07 | 0.01476778 | 0.006604352 | Kg/m |
| 4 | 0.856688531 | | -0.02524349 | 0.000637234 | | | |
| 5 | 0.889485192 | | 0.00755317 | 5.70504E-05 | | | |

# MU of Nominal Mass

∑(xi - xm)2= 0.000872349 Kg^2

| Sources of Uncertainty | Value | Type Of Disrtibution | Probability Distribution | Divisor | Divisor Value | Standard Uncertainty | Uncertainty Contribution U(y)^2 | Degrees of freedom V | Sensitivity coefficient C i | |
|---|---|---|---|---|---|---|---|---|---|---|
| Repeatability of Mass u(x4) | 0.01485934 | Type A | Normal | √n | 2.236067977 | 0.006645299 | 4.416E-05 | **4** | **0.006604352** | **Kg** |
| Repeatability of Nominal Mass u(x5) | 0.01476778 | Type A | Normal | √n | 2.236067977 | 0.006604352 | 4.36175E-05 | 4 | 1 | **Kg/m** |
| Uncertainty of Balance u(x6) | 0.008 | Type B | Normal | √n | 2.236067977 | 0.003577709 | 0.0000128 | ∞ | 1 | **Kg** |
| Least count for Balance u(x7) | 0.002 | Type B | Normal | √n | 2.236067977 | 0.000894427 | 0.0000008 | ∞ | 1 | **Kg** |

**c2=dx/dM= 0.993838203** **c2*u4= 0.006604352**

Combined Uncertainty (uM) = SQRT (u(x4)^2 + u(x5) ^2 +u(x6) ^2 +u(x7) ^2 )

**Combined uncertainty for Nominal Mass = U(Nominal Mass)/Average(Nominal mass)=SQRT((u_Mass/Avg_Mass)^2 + (u_Length/Avg_Length)^2)**

u(M)= 0.0076 Kg

**Uc= 0.007573127 Kg/m**

**5.01931E-05**

**Effective Degree of Freedom=** Uc ^4 / (u (L)*c1)^4/v1) + (u (M)*c2) ^4/v2) = **4.042329169**

**Coverage factor K at = 95% Confidence Level, K = 2.776**

**Expanded Uncertainty = Combined Uncertainity (Uc) x Coverage Factor** 0.021023001 Kg/m

**The value of Nominal is 0.8819±0.021- Kg/m with coverage factor k= 2.776 for confidence level of 95%**

**MU in % =± 2.383743877 %**

# Conclusion

The internship focused on evaluating Measurement Uncertainty (MU) in determining mechanical and physical properties of structural steels as per IS 1786:2008, IS 2062:2011, and IS/ISO/IEC 17025:2017 standards. Testing ensured traceability, repeatability, and calibration consistency, enhancing laboratory competence and reliability.

Minor variations in tensile and yield strengths were observed, influenced by batch, equipment, or testing conditions.

Key Insights:

- Higher repeatability → lower MU
- Fewer, well-calibrated instruments → better accuracy
- Multiple instruments/operators → higher variability

Significance:

- Improves quality control and structural safety
- Supports standardization and NABL accreditation

Future Scope:

- Develop MU optimization and AI/ML predictive tools
- Conduct inter-laboratory comparisons (ILC)

Overall:

Measurement Uncertainty is a key indicator of confidence, reliability, and technical competence in material testing.

# REFERENCES

1)IS 1786:2008 -HIGH STRENGTH DEFORMED STEEL BARS AND WIRES

2) IS 2062:2011-HOT ROLLED MEDIUM AND HIGH TENSILE

STRUCTURAL STEEL

3)National Accreditation Board for Testing and Calibration Laboratories (NABL)

4)IS 1608 , IS 808 ,Technical Paper by JP Jordan

5)TEST REPORT FROM UTM SOFTWARE, OTHER DEVICES.

# THANK YOU

To Be Continued.....