# A Comparative Study on Behavior of Reinforced Concrete Slab using HYSD and TMT Bar

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***Abstract: -*** The manufacturing industry consistently seeks innovations in materials and techniques to enhance the strength, longevity, and cost-efficiency of structures. This study offers a thorough comparison of high-yield strength deformed (HYSD) bar manufactured by Stark Industries and thermo-mechanically treated (TMT) bar, two frequently employed reinforcement materials in construction, with a primary focus on their application in a two-way reinforced concrete slab design. The investigation commences with an examination of the characteristics of both steel bars, including their mechanical strength, ductility, corrosion resistance, and durability. Both materials undergo rigorous mechanical testing to establish their tensile and yield strengths, forming the basis for a direct strength evaluation. A two-way slab design is executed, adhering to design codes and standards, with the determination of trial depth, effective span, and load considerations. The performance assessment encompasses deflection analysis, stability against wind and seismic forces, and displacement criteria. Comparative insights are drawn between the deflection characteristics of the two designs, and their structural stability is evaluated. The project extends to a comprehensive cost-effectiveness analysis, accounting for initial material costs, long-term durability, maintenance expenses, and overall life cycle costs for both steel bars. The findings yield valuable insights into the economic implications of material selection, offering recommendations based on the analysis to assist professionals in choosing the most suitable reinforcement material for specific construction scenarios. The outcomes of this study can be used for decision-making processes with the aim of promoting a more resilient, sustainable, and cost-effective built environment.

***Keywords****: Construction durability, HYSD, TMT, structural design, strength*

## 1. Introduction

A structure refers to a system of connected parts used to support forces (loads). Buildings, bridges, and towers are examples of structures in civil engineering. A building structure consists of walls, floors, roofs, and foundations. In bridges, the structure consists of a deck, supporting systems, and foundations. In towers, the structure consists of vertical, horizontal, and diagonal members along with a foundation. A structure can be broadly classified as (i) a substructure and (ii) a superstructure. The portion of the building below ground level is known as the sub-structure, and the portion above the ground is called the super-structure. A foundation is a substructure, and plinths, walls, columns, floor slabs with or without beams, stairs, roof slabs with or without beams, etc. are superstructures. Many naturally occurring substances, such as clay, sand, wood, rocks, and natural fibers, are used to construct buildings. Apart from this, many man-made products are used in building construction. Bricks, tiles, cement concrete, concrete blocks, plastic, steel, glass, etc. are man-made building materials. A slab is a flat, two-dimensional planar structural element with a small thickness compared to its other two dimensions. It provides a working flat surface or a covering shelter in buildings. It primarily transfers the load by bending in one or two directions. Reinforced concrete slabs are utilized for the construction of bridge decks, walls, roofs, and floors of a building structure. A structure's floor system can take several forms, including precast components, ribbed slabs, in-situ solid slabs, etc. Slabs can be anchored by an all-encompassing concrete beam, a beam made of steel, a wall, or immediately above the column.

Concrete slabs are designed similarly to beams and function largely as flexural elements (Rafi et al., 2014). When a slab is supported only on two parallel, opposite edges, it spans only in the direction perpendicular to the two supporting edges. Such a slab is called a one-way slab. Also, if the slab is supported on all four edges and the ratio of longer span (Ly) to shorter span (Lx), i.e., Ly/Lx > 2, practically the slab spans across the shorter span. Such a slab is also designed as a one-way slab. In this case, the main reinforcement is provided along the spanning direction to resist one-way bending. A rectangular slab supported on four edge supports that bends in two orthogonal directions and deflects in the form of a dish or saucer is called a two-way slab. For a two-way slab, the ratio of Ly/Lx shall be ≤ 2.0. Since the slab rests freely on all sides, due to the transverse load, the corners tend to curl up and lift up. The slab loses contact with some regions. This is known as the lifting of the corner. These slabs are called two-way, simply supported slabs. If the slabs are cast monolithically with the beams, the corners of the slab are restrained from lifting. These slabs are called restrained slabs. At the corner, the rotation occurs in both directions and causes the corners to lift. If the corners of the slab are restrained from lifting, a downward reaction results at the corner, and the end strips get restrained against rotation. However, when the ends are restrained and the rotation of the central strip still occurs, causing rotation at the corner (the slab is acting as a unit), the end strip is subjected to torsion.

Concrete is a substance made artificially by hardening a particular quantity of coarse aggregate, fine aggregate, cement, and water (Bhandari et al., 2011). Depending on the quality and proportions of the ingredients used in the mix, the properties of concrete vary almost as widely as those of different kinds of stones. Concrete has sufficient compression strength but inadequate tension strength. As a result, concrete is brittle in torsion, shear, and bending. As a result, ordinary concrete is only used in situations requiring high compressive strength and weight and where tensile stresses are either non-existent or extremely low (Bhandari et al., 2011). Cracking of concrete occurs whenever the tensile stress developed is greater than the tensile strength of the concrete. This happens due to the large values of the following:

- Flexural tensile stress because of excessive bending under the applied load
- Diagonal tension due to shear and torsion
- Direct tensile stress under applied loads
- Lateral tensile strains accompany high-axis compressive strains due to Poisson's effect.
- Settlement of supports

In addition to the above reasons, cracking also occurs because of restraints against volume changes due to shrinkage, temperature creep, chemical effects, and anchorage failures. Cracking spoils the aesthetics of the structure and also adversely affects the durability of the structure. The presence of wide cracks exposes the reinforcement to the atmosphere, due to which the reinforcements get corroded, causing the deterioration of concrete. In some cases, such as liquid-retaining structures and pressure vessels, cracks affect the basic functional requirement itself (such as water tightness in a water tank). Steel is used as the reinforcing material in concrete to increase its tension. Steel, as such, is good in tension as well as in compression. Steel bars include deformed bars, plain bars, wire, fabric, and steel products, all of which increase the tensile and compressive stress-carrying properties of concrete. Steel reinforcement is also an essential contributor to the crack control of concrete structures. Moreover, the reinforcing bars or rods are commercially available in some specific diameters. Normally, steel bars up to 12 mm in diameter are designated as bars that can be coiled for transportation. Bars more than 12 mm in diameter are termed rods, and they are transported in standard lengths. Like concrete, steel also has several types or grades. The four types of steel used in concrete structures are given below:

- Mild steel bars
- Cold-twisted deformed bars (CTD)
- High-yield strength deformed bars (HYSD)
- Thermomechanically treated steel bars (TMT)

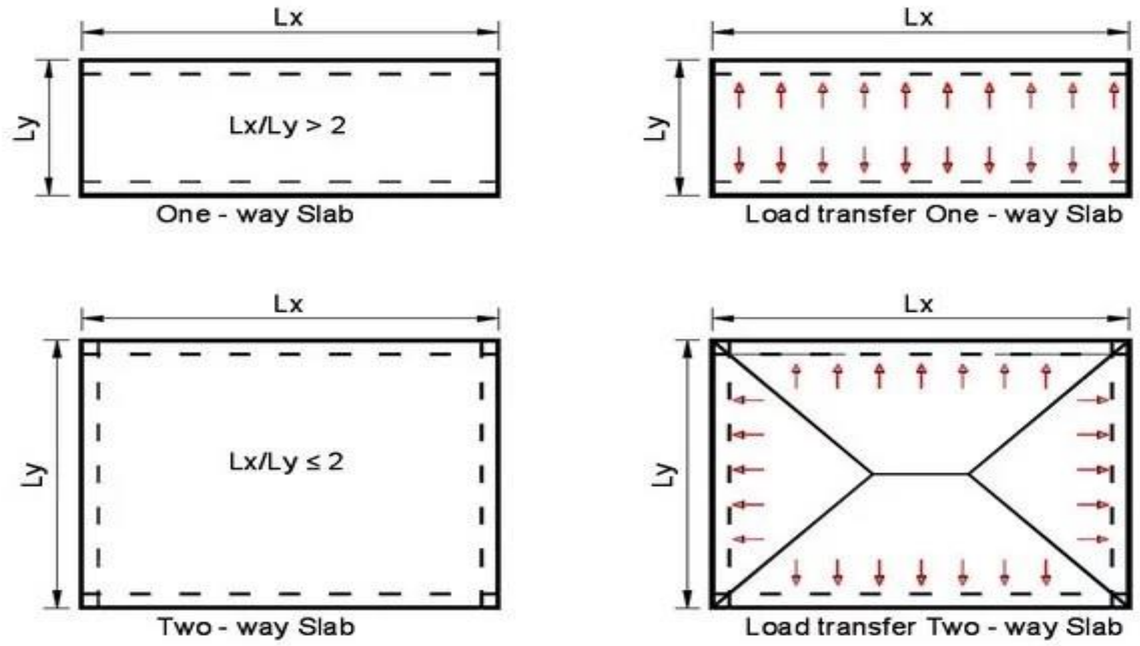



**Fig.** 1 Load transfer mechanism in one-way and two-way slabs

In building construction, CTD, HYSD, and TMT bars are used as primary reinforcement, i.e., main steel, and mild steel bars are used as secondary reinforcement, such as ties, stirrups, and distribution steel. Generally, mild steel of 6 mm in diameter is used as secondary reinforcement, and deformed bars of 8, 10, 12, 16, 20, 25, 32, and 40 mm are used as main reinforcement. Mild steel bars have been progressively replaced by HYSD bars, and subsequently, TMT bars have been promoted in our country. The implications of adopting different kinds of blended cement and reinforcing steel should be examined before adopting them. In the area of structural engineering, the layout and analysis of constructing components stand as a cornerstone for ensuring the safety, durability, and performance of constructed environments. The significance of reinforcing substances in production cannot be overstated, as they play a pivotal function in defining the structural integrity and sturdiness of various elements. The HYSD bar, boasting an impressive energy of 1700 N, emerges as a contender against the familiar TMT bar, with a maximum strength of 550 N.

## 2. Literature Review

A composite material consisting of steel bars embedded in a matrix of hardened concrete, conventional reinforced concrete is one of the most often used building materials in the world. Concrete has a high compressive strength but a low tensile strength due to its physical characteristics. The tensile strength of concrete is typically 10% of its compressive strength. Therefore, the purpose of adding steel reinforcing bars to concrete is to increase the concrete member's ability to withstand conventional internal forces like bending moments, torsional moments, shear forces, axial forces, etc. (Adom-Asamoah and Kankam 2008). Previous studies on the steel bars' chemical and physical characteristics revealed that their high levels of phosphorus, sulfur, and carbon contributed to their low ductility and high yield strength (Kankam and Adom-Asamoah, 2002). In brittle failure modes, twelve reinforced concrete beams tested under cyclic and monotonic loads abruptly collapsed (Kankam and Adom-Asamoah, 2002). Research was done on the steel bars' slip properties and resilience to anchoring bonds in pull-out specimens and beams (Kankam, 2004). It was determined that the bars' ultimate bond strength, formed at the ultimate steel stress, was more than that of regular mild steel bars and on par with high-yield bars (Adom-Asamoah and Kankam 2008). The existence of surface lugs, which are often required for high-yield steel, was frequently used to explain this. Because the concrete in between cracks helps to withstand tensile loads, reinforced concrete elements that are subjected to axial strain become more rigid after the concrete fractures than bare steel reinforcement.

In reinforced concrete buildings, the use of high-tension bars can minimize the amount of steel used and provide additional room for bar arrangement in members, enhancing workability, reducing construction time, and using joint details. As of right now, longitudinal bars can have design yield strengths of up to 600 MPa, according to Euro Code II (Lim and Lee, 2021). The United States and Japan are also increasingly allowing the use of high-tension bars. The top limit of the design yield strength for longitudinal bars in concrete structures in South Korea is 550 MPa, according to the current design standard (Lim and Lee, 2021). This seems to imply that longitudinal bars with a design yield strength of 600 MPa or more might be employed for special research after their effectiveness has been demonstrated via experimentation (Baran and Arsava, 2012; Lim and Lee, 2021). Conversely, flexural members may be more vulnerable to brittle flexural failures, in which concrete breaks by crushing in compression before steel yields, as a result of the high yield strain of Grade 690 MPa HS steel bars (Aldabagh et al., 2018; Lim and Lee, 2021).

Reinforcing bars at crack planes use bond stresses between the reinforcement and surrounding concrete to bridge tensile stresses over fissures. Therefore, it is necessary to provide enough steel bars to retain the reinforcement's capacity to transfer tensile stresses. Members made of reinforced concrete have undergone experimental testing under uniaxial stress (Kang et al., 2017; Fields and Bischoff, 2004). According to Pandya et al. (2013) research on the damage characteristics of fractured TMT reinforcement bars, TMT bars have quickly supplanted traditional HYSD bars in RCC buildings. The surface hardness of TMT bars is changed as a result of heat treatment. These bars' crack initiation and propagation properties differ greatly from those of traditional HYSD bars. Micro-cracks commonly arise in bent areas of bars, although they can also appear in straight sections owing to unintentional overloads. Due to the 90-degree bends, prominent fractures may form in numerous areas, such as beam ends. These fractures impair load-bearing capacity and may cause failure at stress levels far lower than the yield stress. Furthermore, surface fractures at bends are bigger in bars with diameters greater than 16mm, exacerbating their effect on the bars (Pandya et al., 2013).

## 3. Methods of analysis

The developed model is analyzed using ETABS software, which is a modern structural evaluation and design software extensively used within the field of civil engineering and architecture. It permits the advent of targeted and correct 3D systems. The software allows for the modeling of complicated structural structures, accounting for various load conditions, cloth homes, and layout constraints. It provides a platform for simulating real-global structural conduct in unique scenarios. Utilizing this software streamlines the analysis system, complements accuracy, and helps the exploration of several design alternatives, making it a valuable device in current structural engineering. Manual calculation of the result obtained from the software is also done to check for errors. Manual calculations are essential for verifying the outcomes received from software program analysis. Engineers carry out hand calculations to move-check important parameters, which include stresses, deflections, and load distribution.

### 3.1 Test result for a specific material

The tensile strengths of both TMT and HYSD steel bars are determined in the laboratory using a universal testing machine (UTM) and reported in the form of a table (see Tables 1 and 2). The % elongation in TMT steel is higher than that in HYSD steel.

**Table 1** Tensile test result of TMT bar

| S. N. | Diameter ($D_0$ mm) | Cross sectional area ($mm^2$) | Young's Modulus (GPa) | Ultimate Tensile Strength (MPa) | Ultimate load (kN) | Yield strength (MPa) | Yield load (kN) | Elongation (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 50.24 | 195 | 1054.53 | 52.98 | 783.24 | 39.35 | 10 |
| 2 | 8 | 50.24 | 194 | 1001.39 | 50.31 | 777.27 | 39.05 | 9.5 |
| 3 | 8 | 50.24 | 196 | 1042.00 | 52.35 | 795.18 | 39.95 | 10.5 |
| Average | | | 195 | 1032.64 | 51.88 | 785.23 | 39.45 | 10 |

**Table 2** Tensile test result of HYSD bar (Stark steel)

| S. N. | Diameter ($D_0$ mm) | Cross sectional area ($mm^2$) | Young's Modulus (GPa) | Ultimate Tensile Strength (MPa) | Ultimate load (kN) | Yield strength (MPa) | Yield load (kN) | Elongation (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5.2 | 21.23 | 192 | 1956 | 41.52 | 1740 | 36.94 | 5.20 |
| 2 | 5.2 | 21.23 | 189 | 1945 | 41.29 | 1785 | 37.89 | 5.50 |
| 3 | 5.2 | 21.23 | 190 | 1864 | 39.57 | 1805 | 38.32 | 5.42 |
| Average | | | 190 | 1921 | 40.78 | 1776 | 37.70 | 5.37 |

**Table 3** Parameters for building model design

| S. N. | Parameters | Description |
|---|---|---|
| 1 | No. of Stories | Base+5 |
| 2 | Base to plinth | 0.6 m |
| 3 | Floor Rise | Ground floor to 1st floor: 4 m, 1st to 5th floor: 3.2 m |
| 4 | Internal Wall | Interior and Exterior wall: 150 mm thick |
| 5 | Material | Concrete: M30 and reinforcement: Fe500 |
| 6 | Frame Size | Building size: 10.66 m (34.97 ft.) * 13.40 m (43.96ft) |
| 7 | Sizes of Columns(mm) | 300 x 600 |
| 8 | Sizes of Beams(mm) | 230 x 450 |
| 9 | Depth of Slab(mm) | 150 |
| 10 | Total height | 20.60 m |

**Table 4** Specifications for structural analysis of a building

| S. N. | Parameters | Values |
|---|---|---|
| 1 | DL | ETABS estimates the structure's own weight (dead loads) with a factor of 1, while other load cases are set to zero in the load cases section |
| 2 | LL on roof and floors | 2 kN/$m^2$ (roof) and 3 kN/$m^2$ (Floors) as per IS:875 (part -2) |
| 3 | FF on roof and floors | 1 kN/$m^2$ as per IS:875 (part -2) |

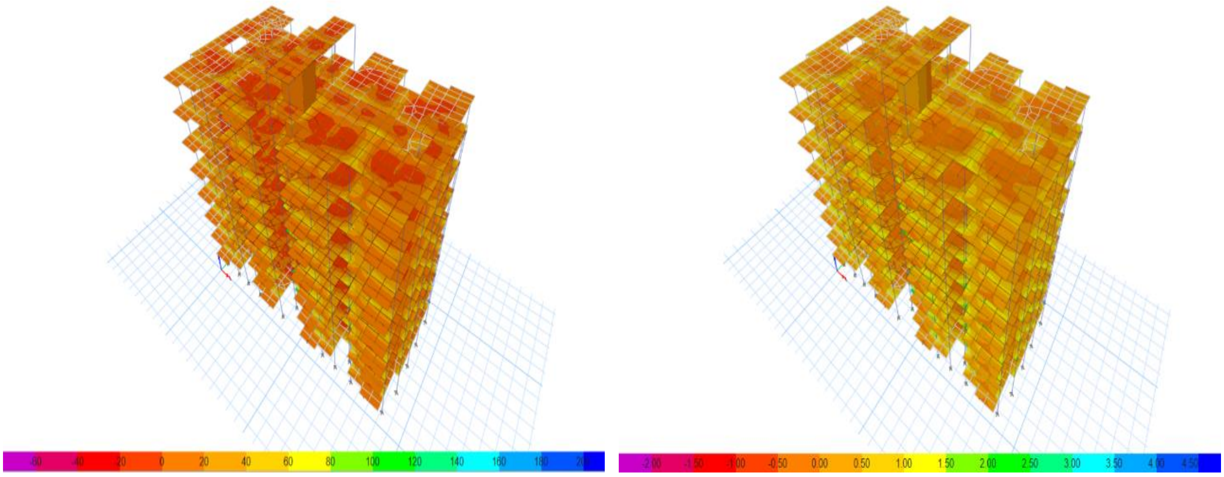
**Table 5** Information required for the study of seismic forces

| S. N. | Parameters | Values as per IS 1893:2016 (Part 1) | References |
|---|---|---|---|
| 1 | Type of Structure | An exclusive RC moment-resisting frame | Table 9, Clause 7.2.6 |
| 2 | Seismic Zone | II | Table 3, Clause 6.4.2 |

| | | | |
|---|---|---|---|
| 3 | Location | Nagpur | Annex E |
| 4 | Zone Factor(Z) | 0.16 | Table 2, Clause 6.4.2 |
| 5 | Type of soil | Rock or Hard Soil | Clause 6.4.2.1 |
| 6 | Damping | 5.0 % | Clause 7.2.4 |
| 7 | Response spectrum | IS 1893(Part 1): 2016 | Fig. 2, Clause 6.4.6 |
| 8 | Load consideration | 1.5(DL + LL)<br>1.2(DL+LL+EL)<br>1.5(DL+EL)<br>0.9DL+1.5EL | Clause 6.3.1 |
| 9 | Response reduction factor (R) | 5 | Table 9, Clause 7.2.6 |
| 10 | Importance factor (I) | 1 | Table 8, Clause 7.2.3 |

**3.2. Analysis of strain, stress, and deflection in the slab**

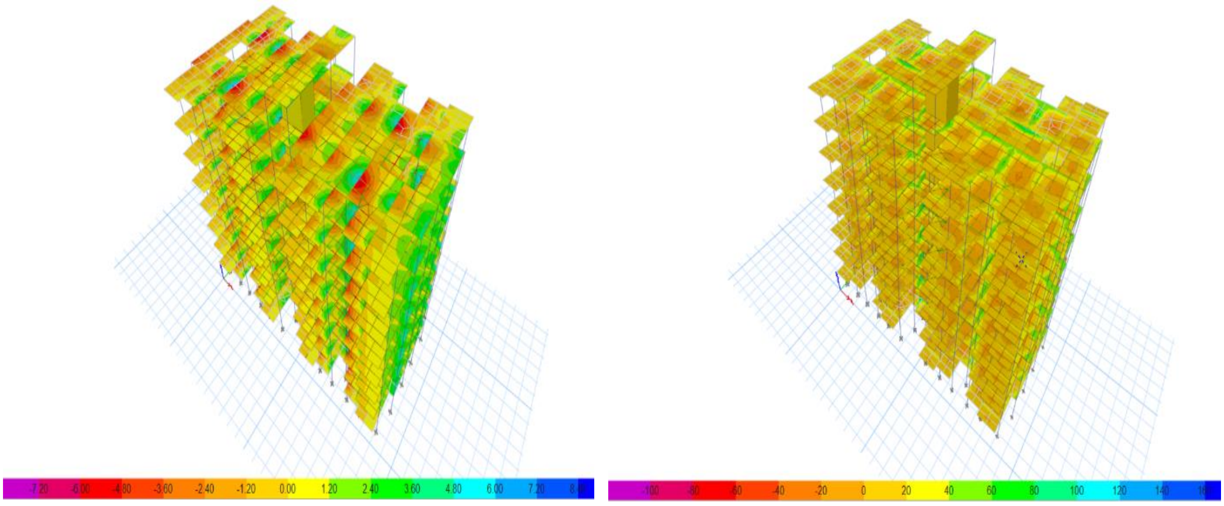
In this work, two different models were considered using TMT and HYSD steel bars for the purpose of analyzing the slab. Slab deflection, stress, and strain developed are measured using the ETAB software for the G+5 building. TMT steel has a lower strength (500 N) compared to HYSD steel (1700 N); this implies that TMT steel might undergo higher strain for the same applied force due to its lower strength-to-force ratio. However, this doesn't necessarily mean that the strain is directly proportional to the strength of the material. Strain is influenced not only by strength but also by other material properties like elasticity, ductility, and the applied load. When designing structures, engineers evaluate these properties to ensure that the strain remains within acceptable limits for the materials used, irrespective of the differences in their strength.



(a) Reinforced by TMT bar (b) Reinforced by HYSD bar

**Fig. 2** Strain developed in each slab of the multi-story building

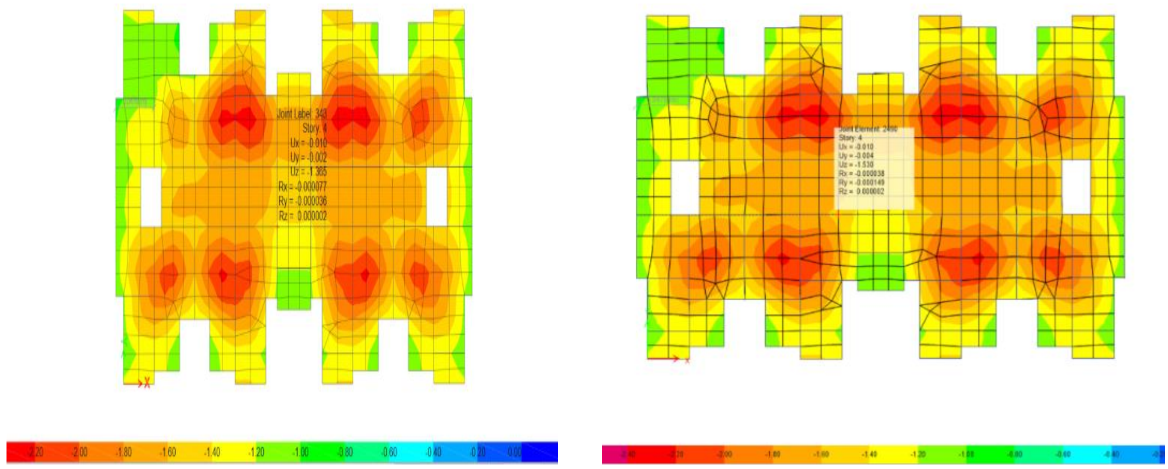
In this structure, both TMT steel (with strength of 500 N) and HYSD steel (with strength of 1700 N) are utilized, and the stress levels can indeed vary between the two materials. Given that TMT steel has a lower strength compared to HYSD steel, when subjected to the same forces within the structure, TMT steel would experience higher stress due to its lower strength-to-force ratio.



(a) Reinforced by TMT bar (b) Reinforced by HYSD bar

**Fig. 3** Stress developed in each slab of the multi-story building

For "HYSD," the deflection is measured at 3.969mm, and the corresponding stress is 568.1. For "TMT," the deflection is measured at 3.384mm, and the corresponding stress is 167.09. The difference in stress between "HYSD" and "TMT" steel is likely due to variations in their internal structures. In "HYSD" steel, the spacing between structural elements is greater, resulting in fewer defects and higher stress resistance. On the other hand, in "TMT" steel, the closer spacing can lead to more defects, making it more prone to deformation under stress and thus having a lower stress value. These differences in spacing are influenced by factors such as material composition and manufacturing processes.



(a) Reinforced by TMT bar (b) Reinforced by HYSD bar

Fig. 4 Maximum value of deflection in each slab of the multi-story building

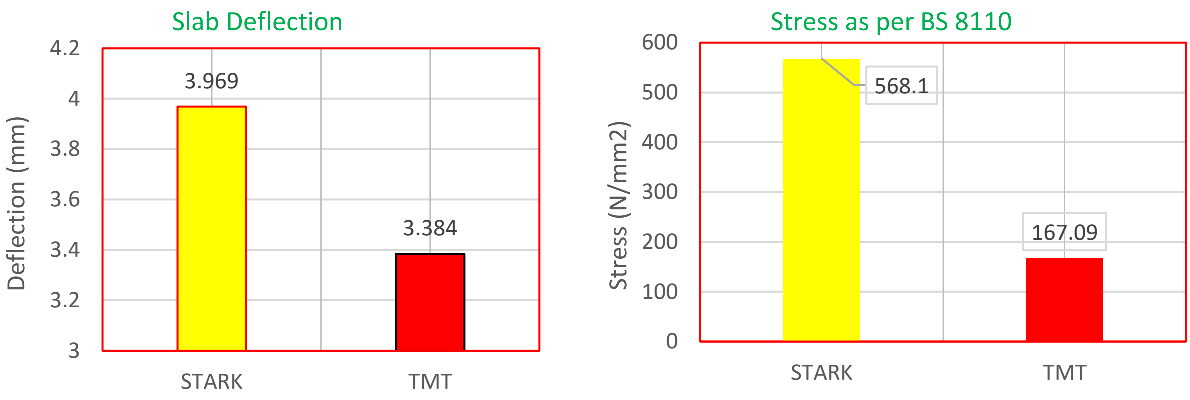



**Fig. 5** Comparison of deflection and stress in slab reinforced by HYSD and TMT steel

### 3.3 Story Displacement

Comparison for story displacements RSX and RSY between the TMT bar and the HYSD steel building model: Analyzing the obtained graphs (Figs. 6 and 7), it is evident that the percentage change in story displacement (both RSX and RSY) for the symmetrical building is lower in the conventional slab design model compared to the grid slab design model. Specifically, the variation is approximately 23.86% for RSX and around 28.26% for RSY when transitioning from a conventional to a grid slab design model.

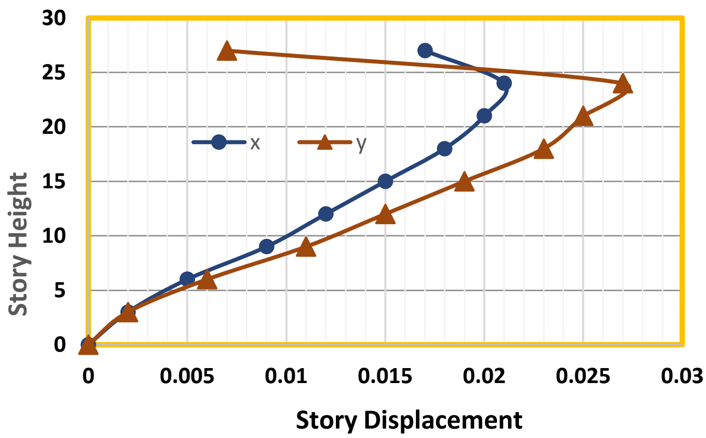



**Fig. 6** Story displacement when TMT steel is used in the building

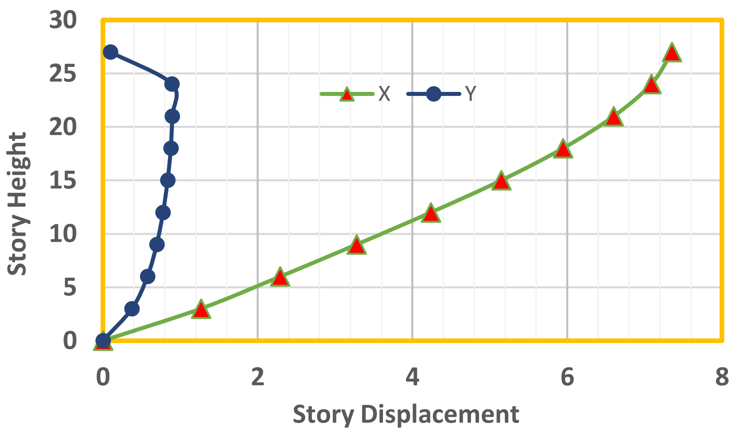


**Fig. 7** Story displacement when HYSD steel is used in the building

## 4. Result and Discussions

The results obtained were shown in the form of tables and discussed under each head (Tables 6 and 7).

Table 6 Result obtained for both HYSD and TMT bar used in the model

| S. N. | Properties | Result obtained |
|---|---|---|
| HYSD bar | | |
| 1 | Size of slab | 3 m x 3.5 m |
| 2 | Check for deflection | Using ETABS software values as per IS 456-2000 |
| 3 | DL 1 and LL 1 aspect | As according to our design our Uz=1.365, Max=2.688, Min=0.368 |
| 4 | Maximum deflection | Minimum of (axial shortening * creep coefficient; span/350 or 200 mm = ((2.668-1.365) x 3, 12/350, 20 mm) = 3.969 mm < Allowable deflection of 34 mm<br>Creep is always taken three for check Deflection |
| TMT bar | | |
| 5 | Check for deflection | Using ETABS software values as per IS 456-2000 |
| 6 | DL 1 and LL 1 element | As according to our design our Uz=1.530, Max=2.658, Min=0.383 |
| 7 | Maximum deflection | Minimum of (axial shortening * creep coefficient; span/350 or 200 mm = ((2.668-1.530) x 3, 12/350, 20 mm) = 3.384 mm < Allowable deflection of 34 mm<br>Creep is always taken three for check Deflection |

Table 7 Result obtained for both model I and II using TMT and HYSD steel

| S. N. | Properties | TMT steel design | HYSD steel design |
|---|---|---|---|
| **Model I** | | | |
| 1 | Shorter Span (Mx) | ✓ Required steel area (Ast) 102.76 mm²<br>✓ Bar diameter: 10 mm<br>✓ Bar spacing (S): 300 mm (or 3d)<br>✓ Recommended: Provide 10 mm bars at 300 mm c/c distance | ✓ Required steel area (Ast): 63.30 mm²<br>✓ Bar diameter: 5.2 mm<br>✓ Bar spacing (S): 300 mm (or 3d)<br>✓ Recommended: Provide 5.2 mm bars at 300 mm c/c distance |
| 2 | Longer Span (My) | ✓ Required steel area (Ast): 29 mm²<br>✓ Bar diameter: 10 mm<br>✓ Bar spacing (S): 300 mm (or 3d)<br>✓ Recommended: Provide 10 mm Ø at 300 mm c/c distance | ✓ Required steel area (Ast): 29 mm²<br>✓ Bar diameter: 5.2 mm<br>✓ Bar spacing (S): 300 mm (or 3d)<br>✓ Recommended: Provide 5.2 mm bars at 300 mm c/c distance |
| Both designs use the same bar spacing of 300 mm for convenience. The specific diameters of bars have been determined based on the calculated steel areas, and the spacing conforms to the specified limit of 300 mm or 3 times the effective depth (3d), whichever is smaller. | | | |
| **Model II** | | | |
| 3 | Horizontal Reinforcement (Top and Bottom) | ✓ Bar diameter: 8mm<br>✓ Ast: 341.97 mm²<br>✓ Spacing: 140mm c/c | |

| | | | |
|---|---|---|---|
| 4 | Vertical Reinforcement (Mesh) | ✓ Bar diameter: 8mm<br>✓ Ast: 251.86 mm²<br>✓ Spacing: 190mm c/c | ✓ Bar diameter: 5.2 mm<br>✓ Size of mesh: 800 mm<br>✓ Spacing: 250 mm in both X and Y directions |
| 5 | Torsion Steel | ✓ Bar diameter: 8mm<br>✓ Ast: 188.89 mm²<br>✓ Spacing: 199.55mm c/c | ✓ Bar Diameter: 5.2 mm<br>✓ Ast: 53.865 mm²<br>✓ Spacing: 259.60 mm |
| 6 | Edge Strip Reinforcement: | ✓ Bar diameter: 8mm<br>✓ Ast: 181.2 mm²<br>✓ Spacing: 280mm c/c | ✓ Bar diameter: 5.2 mm<br>✓ Steel in edge Strip: 181.2 mm² (0.12% of gross area)<br>- Spacing: 110 mm |

**a. Bar diameter**

8 mm for TMT steel whereas 5.2 mm for HYSD steel

**b. Torsion steel**

Larger $A_{st}$ and spacing for TMT steel compared to HYSD steel

**c. Mesh reinforcement**

Larger $A_{st}$ and spacing for TMT steel compared to HYSD steel

**d. Edge Strip Reinforcement:**

Larger $A_{st}$ and spacing for TMT steel compared to HYSD steel

In summary, the TMT steel reinforcement details generally have larger area of steel ($A_{st}$) and spacing (c/c) compared to the HYSD steel reinforcement details. This could indicate that the TMT steel is being used in higher load or more demanding structural applications, as larger $A_{st}$ and spacing values are often used to provide higher strength and load-bearing capacity.

Table 8 Test result of different steel used in this research work

| Steel | TMT | HYSD |
|---|---|---|
| Dia(mm) | 10 mm | 5.2mm |
| Yield stress (N/mm$^2$) | 500 | 1776 |
| Shear strength (N/mm$^2$) | 430.546 | 1736 |
| Slab deflection IS 456-2000 (mm) | 3.384 | 3.969 |
| BS 8110 Part 1(mm) | 2.19 | 2.64 |
| Elongation (%) | 8.310 | 5.37 |
| Horizontal Reinforcement (Top and Bottom in mm$^2$) | 140 (X direction)<br>190 (Y direction) | 250 (Both X and Y direction) |
| Edge Strip Reinforcement (mm$^2$) | 280 | 110 |
| Torsional reinforcement (mm$^2$) | 280 | 259 |
| Weight (g/m) | 620 | 165 |

## 5. Conclusion

In the end, the layout of bolstered concrete slabs entails cautious stability among metallic bar residences, the required location of steel reinforcement (Ast), spacing between bars, and the general structural requirements. The dating between these factors is prompted by employing the power of the metal bars and the thickness of the slab. When using excessive-power metallic bars like the HYSD bars with more energy (1700 N), the specified Ast may be higher, and the spacing among bars may be decreased. This is due to the bars' capability to handle higher masses efficaciously, taking into consideration a greater compact reinforcement format. Conversely, while using low-energy steel bars like TMT bars with a discounted strength of 550 N, a larger Ast is needed to fulfill structural demands. As a result, the spacing among bars will increase to accommodate the extra quantity of metal required for load-bearing capacity.

Based on the results obtained, the following conclusion can be drawn:

- TMT steel has a lower yield stress (500 N/mm$^2$) compared to HYSD steel (1776 N/mm$^2$), indicating that HYSD steel is significantly stronger in terms of resisting deformation under load.
- TMT steel has a slightly lower shear strength (430.546 N/mm$^2$) compared to HYSD steel (1736 N/mm$^2$)
- TMT steel has a larger diameter (10 mm) compared to HYSD steel (5.2 mm).
- Both types of steel have similar a value for slab deflection according to IS 456-2000 and BS 8110 Part 1 standards.
- TMT steel requires higher spacing for horizontal reinforcement (140 x direction, 190 y direction) compared to HYSD steel (250 in both x and y directions).
- TMT steel also requires larger edge strip reinforcement (280 mm) compared to HYSD steel (110 mm).
- Torsional reinforcement requirements are higher for TMT steel (280 mm) than for HYSD steel (259 mm).
- TMT steel has a higher elongation percentage (8.310%) compared to HYSD steel (5.37%), indicating better ductility for TMT steel.
- TMT steel is heavier, with a weight of 620 gm/m, while HYSD steel is lighter, with a weight of 165 gm/m.

In summary, HYSD steel manufactured by STARK Company is significantly stronger and has a higher yield stress compared to TMT steel. However, TMT steel offers better ductility, which can be advantageous in certain applications. The choice between these two types of steel will depend on the specific requirements of the project and the structural demands, considering factors such as strength, ductility, and cost.

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