

Comparison of Compressive Strength, Shear Stress, and Tensile Stress for Load on Column and Load on Foundation Base

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Abstract

The structural behavior of reinforced concrete columns and foundation base slabs subjected to axial loading and reactive forces was investigated in this study. The analysis focuses on the effect of upward reactive components generated by concrete resistance in columns and soil pressure beneath foundation bases. Since upward reactions are present in both structural elements, the corresponding lateral loads and resulting stresses were evaluated to verify the adequacy of the proposed design. A reinforced concrete column carrying an axial load of 120 tonnes was considered. The column was assumed to have a square cross-section of 500 mm × 500 mm and was designed using M30 grade concrete. Direct compressive stress calculations were performed considering the permissible compressive stress of concrete. The results indicated that the developed compressive stress remained within the allowable limits, confirming the adequacy of the selected column dimensions. The upward reactive component in the column was further considered in the evaluation of lateral loading and associated shear stresses. Similarly, a foundation base subjected to the same load of 120 tonnes was analyzed. The foundation was designed to distribute the structural load over a larger area, considering an allowable soil bearing capacity of 30 t/m². Due to the comparatively lower strength of soil relative to concrete, a larger foundation size was required to ensure safe load transfer. The lateral load was calculated using a coefficient of 0.217, resulting in a lateral force of approximately 26 tonnes. Shear stress evaluations for both the column and foundation slab demonstrated that the induced stresses were within the permissible shear strength limits of M30 concrete. The tensile stresses developed due to bending effects were also examined. The analysis showed that both tensile and shear stress remained below allowable values, indicating that the column and foundation base slab are structurally safe under the combined effects of axial load, lateral load, and upward reactive forces.

Keywords: Reinforced concrete column, foundation base slab, axial load, upward reaction, soil pressure, lateral load, compressive stress, shear stress, tensile stress, M30 concrete, structural safety, Foundation design

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INTRODUCTION

The safety and performance of structural systems depend on their ability to resist the axial, shear, bending, and tensile forces generated under service conditions. Structural elements, such as columns, beams, and foundations, are subjected to a combination of loads and reactions that influence their stress distribution and deformation characteristics. A comprehensive understanding of these effects is essential for ensuring structural stability, serviceability, and economic design.

Columns primarily resist the axial compressive loads transmitted from the superstructure. The presence of upward reactive forces within the structural system generates additional stress conditions that must be evaluated to verify the adequacy of the selected cross-section. Similarly, foundation base slabs are designed to safely transfer structural loads to the supporting soil. Because soil possesses significantly lower strength than concrete, larger foundation dimensions are generally required to maintain stress within permissible limits. The interaction between the applied loads and upward soil reactions plays a critical role in the design and performance of foundations [1–4].

In addition to direct compressive stress, structural elements are subjected to shear and tensile stresses arising from lateral loading and bending. These stresses influence the load-carrying capacity of reinforced concrete members and must be checked against the permissible values specified by the design codes. The proper evaluation of shear and tensile stresses ensures the structural safety of both columns and foundations under combined loading conditions [5–7].

Beam elements are particularly sensitive to the span length, load intensity, member dimensions, and material strength. Variations in these parameters directly affect the bending moments, deflections, and required structural depth. Therefore, understanding the relationship between the span, load intensity, beam width, and concrete strength is essential for optimizing the structural design [8–10].

This study investigated the behavior of reinforced concrete columns, foundation base slabs, and beams subjected to axial loads, lateral forces, and bending effects. The analysis evaluates compressive, shear, and tensile stresses and examines the influence of span length, load intensity, beam width, and concrete strength on the structural performance. These findings provide useful insights into the safe and economical design of reinforced concrete structures [11].

METHODOLOGY

This study evaluated the structural behavior of reinforced concrete columns, foundation base slabs, and beams subjected to axial loading, lateral forces, shear stresses, tensile stresses, and bending effects. The methodology is based on analytical calculations using the standard principles of reinforced concrete design and permissible stress theory [12].

Analysis of Reinforced Concrete Column

A reinforced concrete column carrying an axial load of 120 tonnes was considered in this study. The column was assumed to have a square cross-section of 500 mm × 500 mm and was constructed using M30 grade concrete. The direct compressive stress was calculated by dividing the applied load by the cross-sectional area of the column. The computed stress was compared with the permissible compressive stress of concrete ($\sigma_{cc} = 8 \text{ N/mm}^2$) to verify the structural adequacy [13].

The effect of the upward reactive component developed within the column was also considered in this study. Because the reaction acts opposite to the applied load, the lateral loading effects were evaluated using a lateral load coefficient of 0.217 [14].

Analysis of Foundation Base Slab

The foundation base slab was designed to support an axial load of 120 tonnes. The supporting soil was assumed to possess a safe bearing capacity of 30 t/m². The required foundation area was determined by dividing the applied load by the allowable soil pressure, as follows: The upward soil reaction was considered in the analysis to evaluate the stress distribution and foundation safety [15].

Because the strength of the soil is significantly lower than that of concrete, a larger foundation area was adopted to ensure safe load transfer from the structure to the ground.

Shear Stress Evaluation

The lateral load acting on both the column and foundation was calculated as:

$$\text{Lateral Load} = 0.217 \times 120 = 26 \text{ tonnes}$$

For the column, the lateral load was assumed to act tangentially over a beam section with a width of 300 mm and an effective depth of 600 mm. The corresponding shear stress was calculated and compared with the permissible shear strength of the M30 grade concrete.

For the foundation base slab, the same lateral load was considered to act over a foundation width of 2 m and slab thickness of 250 mm. The resulting shear stress was evaluated and checked against the allowable concrete shear stress values.

Tensile Stress Evaluation

The bending effects in the column generate tensile stress within the concrete section. The tensile stress was determined by dividing the applied tensile force by the corresponding cross-sectional area of the specimen. The calculated tensile stress was compared with the permissible tensile strength of M30 grade concrete to verify structural safety.

Similarly, the tensile stresses in the foundation base slab were evaluated by considering the lateral load acting on the slab width and thickness. The resulting stresses were checked against the permissible values to ensure adequate performance.

BEAM ANALYSIS

A reinforced concrete beam carrying a uniformly distributed load of 2 t/m over a 6 m span was analyzed. The required effective depth was determined using the bending equation and permissible bending compressive stress of M30 concrete.

The influence of various parameters on beam behavior was investigated through a parametric study:

Case I: Increase in Span Length

The beam span increased by 20%, from 6.0 to 7.2 m, while maintaining a constant load intensity. The resulting changes in the beam depth and deflection were evaluated.

Case II: Increase in Load Intensity

The uniformly distributed load increased by 20%, from 2.0 t/m to 2.4 t/m, while maintaining the original span length. The corresponding variations in the beam depth and bending response were determined.

Case III: Increase in Beam Width

The beam width was increased by 20% to study the effect of increased rigidity on structural behavior. The required effective depth and bending characteristics were recalculated.

Case IV: Increase in Concrete Strength

The permissible bending compressive stress (σ_{cbc}) increased by 20%, which corresponded to a higher concrete strength. The effects on the beam depth and overall structural efficiency were evaluated.

Comparative Assessment

The results obtained from the column, foundation, and beam analyses were compared to assess the influence of the geometry, material strength, span length, and loading conditions on the structural performance. Particular emphasis was placed on identifying the parameters that most significantly affected bending, deflection, and stress development. The calculated stresses and deformations were compared with the permissible limits to determine the adequacy and safety of the proposed structural members.

- In both cases, the upward reactive component is acting. In the column upward reactive component and in the foundation base slab upward soil reaction is acting; hence, for both structures, the lateral load is taken.

Column

- Load on column = 120 t (axial load).
- Since upward reactive components are acting.
- Hence, direct stress taken.

$$\frac{P}{A} = \sigma_{cc} (\text{Permissible compressive stress})$$

$$\frac{120 \times 1000 \times 10}{500 \times 500}$$

Where the cross-section of column $500 \times 500 \text{ mm}^2$ taken.

$$= \frac{1200000}{250000} = 4.8 \text{ N/mm}^2 < 8 \text{ N/mm}^2$$

Because of the upward reactive component due to concrete, $\sigma_{cc} = 8 \text{ N/mm}^2$ is considered. (Permissible compressive stress for M30)

- Hence, the cross-section of column $500 \times 500 \text{ mm}$ is O.K.

Foundation Base

- Load on foundation base = 120 t
- The foundation base distributes the load over a larger area for the safety of the foundation.

↓

Since upward reactive component (soil pressure)

$$\text{Hence, } \frac{120}{30} = 4 \text{ m}^2 = 2 \text{ m} \times 2 \text{ m}$$

Since an upward reaction due to soil is acting, the strength of the soil is taken as 30 t/m^2 taken.

- In the column, the strength of concrete is considered for the upward reactive component, and concrete has high strength; hence, a smaller cross-section of the column is considered. However, in the foundation base slab, the upward reactive component due to soil is acting, and soil has very low strength as compared to concrete; hence, a larger foundation base size is considered. Shear stress: Because the upward reactive component is acting, a lateral load is applied.

$$\text{Lateral load} = 0.217 \times 120 \text{ [Column taken]}$$

$$\frac{1 - \sin \phi}{1 + \sin \phi} \left[[\phi = 40^\circ \text{ for concrete}] \right] \quad \downarrow \text{Load on column}$$

= 26 t = vertical load acting tangentially to depth of beam = 600 mm and 300 mm width

$$\text{Shear stress} = \frac{26 \times 1000 \times 10}{600 \times 300} = \frac{26}{18} = 1.44 \text{ N/mm}^2 < 2 \text{ N/mm}^2$$

[Shear strength of M30 grade concrete]

In the case of the foundation base slab, the upward reactive soil pressure is acting, and a lateral load is applied.

$$\text{Lateral load} = 0.217 \times 120 = 26 \text{ t}$$

$$\frac{1 - \sin \phi}{1 + \sin \phi} \left[[\phi = 40^\circ \text{ for concrete}] \right]$$

This lateral load = vertical load acting tangentially to 2 m foundation width & 250 mm thickness of foundation base

$$\text{Shear stress} = \frac{26 \times 1000 \times 10}{2000 \times 250} = \frac{26}{50} = 0.52 \text{ N/mm}^2 < 2 \text{ N/mm}^2$$

↓

Foundation width = 2 m

(Shear strength of concrete permissible; hence O.K.)

Tensile stress: After bending in column tension develops.

Since upward reaction in column hence lateral load taken i.e. 26 t

$$\text{Tensile stress} = \frac{26 \times 1000 \times 10}{500 \times 500} = \frac{26}{25} = 1.04 \text{ N/mm}^2$$

↓
Cross-section area

$$\text{Tensile strength of M30 grade concrete} \frac{10}{100} \times 30 = 3 \text{ N/mm}^2 > 1.04 \text{ N/mm}^2$$

Hence, O.K.

RESULTS AND DISCUSSION

Structural analyses of the column, foundation base slab, and beam were conducted to evaluate the effects of axial loading, lateral loading, shear stress, tensile stress, and bending behavior. The results obtained from these calculations are discussed below.

Column Analysis

The reinforced concrete column was subjected to an axial load of 120 t. A square cross-section of 500 mm × 500 mm was considered for the analysis. The calculated direct compressive stress was less than the permissible compressive stress of M30 grade concrete ($\sigma_{cc} = 8 \text{ N/mm}^2$). Therefore, the selected column dimensions were adequate and structurally safe.

The upward reactive component that developed within the column was also considered. Based on the adopted lateral load coefficient of 0.217, the corresponding lateral load acting on the column was calculated as

$$\text{Lateral Load} = 0.217 \times 120 = 26 \text{ tonnes}$$

The resulting stress remained within permissible limits, indicating satisfactory structural performance.

Foundation Base Slab Analysis

The foundation base slab was designed to support a load of 120 tonnes while safely transferring the load to the supporting soil. Considering a safe soil bearing capacity of 30 t/m², the foundation dimensions were selected to ensure that the soil pressure remained within the allowable limits.

The analysis showed that the foundation requires a larger area than the column because the strength of the soil is significantly lower than that of concrete. The upward soil reaction effectively balanced the applied load, resulting in safe stress levels throughout the foundation system.

Shear Stress Evaluation

For both the column and foundation base slab, a lateral load of 26 t was considered because of the presence of upward reactive forces.

For the column, the calculated shear stress acting over the beam section (300 mm width and 600 mm depth) was lower than the permissible shear strength of M30 concrete. Hence, the column section was considered safe with respect to shear failure.

Similarly, for the foundation base slab with a width of 2 m and thickness of 250 mm, the computed shear stress was below the permissible limit. Therefore, the foundation base slab satisfied the shear strength requirements.

Tensile Stress Evaluation

The lateral load generates bending effects in the structural members, resulting in tensile stress. The calculated tensile stresses in both the column and foundation base slab were found to be less than the

permissible tensile strength of the M30 grade concrete. Consequently, both structural elements were considered safe for tensile loading conditions.

Beam Analysis

A reinforced concrete beam carrying a uniformly distributed load of 2 t/m over a 6 m span was analyzed. The required effective depth obtained from the bending calculations was approximately 367 mm.

Effect of Span Increase

When the span length increased by 20% from 6.0 m to 7.2 m while maintaining the loading conditions constant, the required beam depth increased to approximately 441 mm.

Findings on Different Situations

- Beam depth increased by approximately 20.16%.
- Deflection increased by approximately 19.84%.
- Span length was found to have a significant influence on bending behavior and structural stiffness.
- Effect of load increase

When the load intensity was increased by 20%, from 2.0 t/m to 2.4 t/m, while maintaining the span constant, the required beam depth increased to approximately 402.39 mm.

- Beam depth increased by approximately 9.64%.
- Deflection increased moderately.
- The influence of load intensity on bending was less significant than that of span length.
- Effect of beam width increase

The beam width increased by 20%, resulting in a width of 480 mm.

- Required beam depth decreased to approximately 335.41 mm.
- Beam depth decreased by approximately 8.61%.
- Increased beam width improved structural rigidity and reduced bending requirements.
- Effect of concrete strength increase

The permissible bending compressive stress was increased by 20%, resulting in $\sigma_{cbc} = 12 \text{ N/mm}^2$.

The required beam depth reduced to approximately 335.41 mm.

Increased concrete strength enhanced load-carrying capacity and reduced section requirements.

Higher-strength concrete improved structural efficiency without increasing member dimensions.

Description of Overall Findings

The study demonstrated that all calculated compressive, shear, and tensile stresses remained within the permissible limits, confirming the safety of the proposed structural members. Among the parameters investigated, the span length had the greatest influence on beam bending and deflection. A 20% increase in span produced approximately a 20% increase in both the required depth and deflection, whereas a similar increase in load intensity resulted in a comparatively smaller increase in beam depth. Furthermore, increasing the beam width and concrete strength improved the rigidity and reduced the required section dimensions. These findings highlight the importance of span control and structural stiffness in achieving an efficient and economically reinforced concrete design.

Tensile stress for foundation base slab: Because of the upward soil reaction, a lateral load of 26 t is acting on a 2 m width of the foundation base and 250 mm thickness of the foundation base; hence, tensile stress

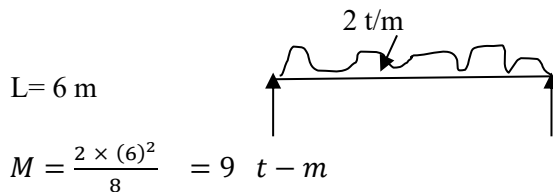
$$\frac{\text{Load}}{\text{Cross Sectional Area}}$$

Tensile stress for foundation base slab

$$= \frac{26 \times 1000 \times 10}{2000 \times 250} = \frac{26}{50} = 0.52 \text{ N/mm}^2 < 3 \text{ N/mm}^2 (\text{Permissible tensile strength of M30 grade concrete})$$

Hence, O.K.

Beam



Using bending equation:

$$\frac{9 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 400 \times d^3 \times \frac{2}{d}} = 10 \rightarrow \sigma_{cbc} \text{ of M30 grade concrete.}$$

$$d = 367 \text{ mm}$$

$$\text{Deflection or bending: } \delta = \frac{5}{24} \times \frac{10 \times (6000)^2}{31219 \times 367} = 6.546 \text{ mm}$$

$$E \text{ for M30 } 5700 \sqrt{30}$$

$$\text{Case I} \rightarrow \text{Span is increased by } 20\% \frac{20}{100} \times 6 = 1.2 \text{ m}$$

$$l = 6 + 1.2 = 7.2 \text{ m}$$

w = const.

$$M = \frac{2 \times (7.2)^2}{8} = 12.96 \text{ t-m}$$

$$\text{Using bending equation: } \frac{12.96 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 400 \times d^3 \times \frac{2}{d}} = 10$$

b & σ_{cbc} = const.

$$d = 441 \text{ m.}$$

Findings (When Depth Increased by 20.16%)

- Owing to a 20% increase in the span of the beam, the depth increased by 20.16%.

$$\text{Bending or deflection: } \delta = \frac{5}{24} \times \frac{10 \times (7.2 \times 1000)^2}{31219 \times 441} = 7.845 \text{ mm} < 20 \text{ mm}$$

Hence, O.K.

Findings (When deflection increased by 19.844%)

- Due to 20% increase in span bending or deflection increases by 19.844%
 w is increased by 20% $l = b = \sigma_{cbc}$ const.

$$\frac{20}{100} \times 2 = 0.4 \text{ t/m}$$

$$w = 2.4 \text{ t/m}$$

$$M = \frac{2.4 \times (6)^2}{8} = 10.80 \text{ t-m}$$

$$\text{Using bending equation: } \frac{10.80 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 400 \times d^3 \times \frac{2}{d}} = 10$$

$$d = 402.39 \text{ mm}$$

Findings (Increase Depth 9.64%)

- Due to increase in load intensity, 20, depth increases by 9.64%.

CONCLUSION

- This study examined the structural behaviors of reinforced concrete columns, foundation base slabs, and beams subjected to axial loads, lateral forces, shear stresses, tensile stresses, and bending effects. The analyses were performed using the permissible stress criteria for M30 grade concrete and standard structural design principles.
- The results demonstrated that the selected column section of 500 mm × 500 mm was adequate for safely resisting the applied axial load of 120 tonnes. The calculated compressive stress remained below the permissible compressive stress of M30 concrete, thereby confirming the suitability of the adopted column dimensions. Similarly, the foundation base slab successfully distributed the applied load to the supporting soil while maintaining the soil pressure within the allowable limits.
- The presence of upward reactive forces in both the column and foundation generated lateral loads equivalent to approximately 26 t. The resulting shear stresses in the column and foundation base slab were lower than the permissible shear strength of concrete, indicating satisfactory resistance against shear failure. Furthermore, the tensile stress developed owing to the bending action remained within the allowable limits, confirming the structural safety of both members under combined loading conditions.
- The beam analysis revealed that the span length had a more significant effect on bending and deflection than the load intensity. A 20% increase in span resulted in an increase of approximately 20% in the required beam depth and deflection, whereas a similar increase in load intensity produced a comparatively smaller increase in the section depth. The study also showed that increasing beam width and concrete strength enhances structural rigidity and reduces the required beam depth.
- Overall, all the structural elements satisfied the requirements for compressive, shear, and tensile strengths. The findings emphasize that span control, adequate member dimensions, and appropriate material strength are critical factors for achieving safe, economical, and efficient reinforced concrete structural designs. The proposed methodology can be effectively applied to the design and assessment of columns, foundations, and beams in practical engineering projects.
- Bending depends on the span, not on the load intensity. More bending occurred due to the increase in span.

In case of increased load intensity bending or deflection:

$$\delta = \frac{5}{24} \times \frac{10 \times (6000)^2}{31219 \times 402.39} = 5.970 \text{ mm} < \text{Bending due to increase in span.}$$

Rigidity

Provided due to increase in width of beam & strength of concrete (σ_{bc})

$$\text{Increase in width of beam: } \frac{20}{100} \times 400 = 80 \text{ mm}$$

Hence, $b = 480 \text{ mm}$

$$M = \frac{2 \times (6)^2}{8} = 9 \text{ t-m}$$

Using bending equation: $\frac{9 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 480 \times d^3 \times \frac{2}{d}} = 10$

$d = 335.41 \text{ mm}$

- Due to 20% increase in width of beam depth decreased by 8.608%

Deflection or bending: $\delta = \frac{5}{24} \times \frac{10 \times (6000)^2}{31219 \times 335.41} = 7.163 \text{ mm}$

σ_{cbc} is increased by 20% $\frac{20}{100} \times 10 = 2 \text{ N/mm}^2$

Hence, $\sigma_{cbc} = 12 \text{ N/mm}^2$

$M = \frac{2 \times (6)^2}{8} = 9 \text{ t-m}$

Using bending equation: $\frac{9 \times 1000 \times 10 \times 1000}{\frac{1}{12} \times 480 \times d^3 \times \frac{2}{d}} = 12$

$d = 335.41$

- In both cases, the rigidity provided by the increase in the width of the beam and strength of the beam decrease in depth of the beam = 8.608%.
- Hence, the rigidity provided by an increase in the width and strength of the beam decreases the depth of the beam.

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