

A REVIEW OF PERFORMANCE ASSESSMENT OF STRUCTURAL FRAMING ELEMENTS USED IN LOW-RISE BUILDING CONSTRUCTION UNDER SERVICE LOADS

Pranjal Tripathi¹, Mr. Ushendra Kumar²

¹Master of Technology, Civil Engineering, Lucknow Institute of Technology, Lucknow, India

²Head of Department, Department of Civil Engineering, Lucknow Institute of Technology, Lucknow, India

Abstract Low-rise buildings constitute a significant portion of global residential and light commercial infrastructure, where structural framing elements must satisfy serviceability and safety requirements under routine loading conditions. This review synthesizes existing research on the performance assessment of primary structural framing elements—beams, columns, slabs, shear walls, and connections—used in low-rise construction under service loads. Emphasis is placed on serviceability limit states, including deflection control, cracking behavior, vibration response, creep and shrinkage effects, and durability-related performance. The review critically evaluates experimental investigations, analytical formulations, and numerical modeling approaches applied to reinforced concrete, structural steel, composite, and timber framing systems. Comparative discussion of major design standards such as IS codes, Eurocodes, ACI, and ASCE provisions is also presented to highlight differences in service load evaluation criteria. The synthesis identifies prevailing assessment methodologies, key influencing parameters (e.g., span-to-depth ratio, reinforcement ratio, slenderness, and material properties), and recurring limitations in current research. Gaps are observed in long-term performance monitoring, probabilistic serviceability assessment, and integrated performance-based evaluation frameworks for low-rise buildings. The findings aim to provide a consolidated technical reference for researchers and practicing engineers while outlining future research directions for improving service load performance assessment methodologies.

Key Words: Structural framing elements; Service loads; Serviceability limit state; Low-rise buildings; Performance assessment; Durability performance

1. INTRODUCTION

1.1 Background

Structural framing elements constitute the primary load-resisting system in low-rise buildings, ensuring stability, serviceability, and safety under routine loading conditions. In typical low-rise construction (generally one to four storeys), gravity load-bearing members such as beams, slabs, and columns are complemented by lateral load-resisting components including shear walls or braced frames. While ultimate limit state (ULS) design governs collapse prevention, serviceability limit state (SLS)

performance often controls member sizing in low-rise systems due to deflection, cracking, and vibration constraints. Modern design standards such as American Concrete Institute (ACI 318) and Bureau of Indian Standards (IS 456) emphasize service load verification to ensure functional performance throughout the structure's design life (ACI, 2019; BIS, 2000). With increasing use of diverse material systems—reinforced concrete, structural steel, engineered timber, and composite framing—performance assessment methodologies have evolved from simplified elastic checks to advance nonlinear numerical simulations and long-term monitoring approaches.

1.2 Importance of Performance Assessment of Structural Framing

Performance assessment under service loads is critical because most structural elements operate within elastic or near-elastic ranges during their lifespan. Excessive deflection may impair non-structural components; uncontrolled cracking can accelerate durability deterioration; and perceptible vibrations may reduce occupant comfort. According to American Society of Civil Engineers (ASCE 7), service load combinations are formulated to reflect realistic operational conditions rather than extreme events. Research demonstrates that serviceability failures frequently precede structural failure and significantly influence lifecycle costs (MacGregor and Wight, 2012). Moreover, durability-related phenomena such as creep, shrinkage, and fatigue progressively affect stiffness and load redistribution, particularly in reinforced concrete and steel systems (Neville, 2011). Therefore, systematic assessment ensures long-term functionality and economic efficiency.

1.3 Scope & Objectives of the Review

This review synthesizes existing literature concerning the performance evaluation of structural framing elements in low-rise buildings under service loads. It covers experimental investigations, analytical models, and numerical simulations addressing deflection behavior, crack development, vibration response, stiffness degradation, and durability performance. Comparative discussion of international standards, including European Committee for Standardization (Eurocode 2 and Eurocode 3), is included to

highlight methodological differences in serviceability verification. The objective is to identify prevailing assessment techniques, key influencing parameters, limitations in existing studies, and research gaps requiring further investigation. The paper does not present new experimental data but critically evaluates published findings to provide a consolidated knowledge framework.

1.4 Service Loads (Dead, Live, Wind, Seismic Quasi-Static Considerations)

Service loads refer to loads expected during normal usage conditions of a structure. Dead loads consist of permanent structural and non-structural components, while live loads arise from occupancy and movable elements. Environmental actions such as wind loads, defined in American Society of Civil Engineers (ASCE 7), are considered at reduced intensity for serviceability checks. In low-rise buildings, seismic actions are typically evaluated under quasi-static or service-level earthquake scenarios to control drift and cracking rather than collapse resistance. Temperature variations and shrinkage-induced stresses also contribute to service-level effects (EN 1990, 2002). Accurate characterization of these loads is essential for realistic performance prediction, particularly when assessing long-term deflection and vibration sensitivity.

1.5 Justification for Focusing on Low-Rise Buildings

Low-rise buildings represent the majority of global residential and small commercial infrastructure, especially in developing regions. Their structural systems are often simplified, making serviceability performance a governing design criterion rather than strength capacity. Unlike high-rise structures, lateral drift demands are typically modest; however, floor vibration, cracking, and durability concerns are more pronounced due to cost-driven design and material variability. Additionally, local building codes such as those issued by the Bureau of Indian Standards provide simplified empirical deflection limits tailored to low-rise construction, necessitating critical evaluation against contemporary research findings. Concentrating on low-rise systems enables targeted synthesis of practical performance assessment methods relevant to common construction practice and emerging sustainability-oriented materials.

2. METHODOLOGY OF LITERATURE REVIEW

2.1 Search Strategy

2.1.1 Databases and Information Sources

The literature survey was conducted using major peer-reviewed academic databases to ensure comprehensive coverage and high-quality sources. Indexed journal articles were primarily retrieved from Scopus and Web of Science due to their extensive coverage of structural engineering publications. Supplementary searches were performed using

Google Scholar to capture conference proceedings and recently published articles not yet indexed. Domain-specific publications were accessed through the ASCE Library to include journals focused on structural performance, materials, and construction engineering. This multi-database approach minimizes publication bias and enhances reproducibility, consistent with systematic review recommendations (Kitchenham and Charters, 2007).

2.1.2 Keywords and Boolean Search Terms

Search queries were structured using Boolean operators to refine relevance. Core keywords included: “structural framing elements,” “low-rise buildings,” “service loads,” “serviceability limit state,” “deflection,” “cracking,” “vibration performance,” and “durability under service conditions.” Boolean combinations such as (“low-rise buildings” AND “serviceability”) and (“reinforced concrete beams” OR “steel frames”) AND (“deflection” OR “crack width”) were applied. Truncation techniques and phrase searching ensured retrieval of variations in terminology. The search process emphasized transparency and repeatability, aligning with established systematic review protocols in engineering research (Tranfield, Denyer and Smart, 2003).

2.2 Inclusion and Exclusion Criteria

2.2.1 Time Period and Study Type

The review primarily considered publications from 2000 to 2025 to reflect contemporary design practices and code developments, while seminal earlier works were included where foundational concepts were necessary. Eligible studies comprised experimental investigations, analytical formulations, numerical simulations (e.g., finite element modelling), and code-based comparative analyses. Purely conceptual papers without quantitative evaluation were excluded unless they contributed significantly to serviceability theory. This approach ensures methodological rigor and relevance to current engineering practice (Snyder, 2019).

2.2.2 Relevance to Service Load Performance

Only studies explicitly addressing structural performance under service-level loading conditions were included. Papers focusing exclusively on ultimate load capacity, collapse mechanisms, or extreme event performance (e.g., progressive collapse under blast loading) were excluded unless they contained serviceability-related findings. Additional screening ensured that reviewed studies examined measurable performance indicators such as deflection limits, crack width control, vibration response, creep effects, or stiffness degradation. This relevance-based filtering enhances the specificity of conclusions related to serviceability assessment.

2.3 Review Framework

2.3.1 Categorization of Literature

The selected literature was organized into thematic categories to facilitate structured synthesis. Studies were first classified by material system: reinforced concrete, structural steel, composite framing, and timber systems. Within each material category, further subdivision was made based on loading type (gravity loads, environmental loads, long-term effects) and performance metric (deflection, cracking, vibration, durability). Such hierarchical categorization improves analytical clarity and allows cross-comparison of methodologies and findings across materials and performance indicators (Denyer and Tranfield, 2009). This framework ensures that the review moves beyond descriptive summarization toward critical synthesis and identification of research gaps.

3. STRUCTURAL FRAMING ELEMENTS IN LOW-RISE BUILDINGS

3.1 Definition and Classification

Structural framing elements in low-rise buildings constitute the primary load-resisting skeleton that transfers gravity and lateral actions safely to the foundation. These elements are generally categorized into flexural members (beams and slabs), axial members (columns), lateral load-resisting components (shear walls or braced frames), and structural connections. In low-rise systems, framing is typically regular and orthogonal, facilitating predictable load transfer mechanisms and simplified analysis procedures (MacGregor and Wight, 2012).

3.1.1 Beams and Slabs

Beams are horizontal flexural members designed to resist bending moments and shear forces induced by gravity loads, while slabs distribute floor loads to supporting beams or directly to columns in flat plate systems. Under service loads, performance is governed by deflection limits, crack width control, and vibration response. Excessive mid-span deflection can impair non-structural components and serviceability performance, particularly in longer spans (Nilson, Darwin and Dolan, 2010).

3.1.2 Columns

Columns are primarily compression members transmitting vertical loads from beams and slabs to the foundation. In low-rise construction, columns typically experience moderate axial loads combined with bending due to frame action. Service-level concerns include slenderness effects, creep-induced shortening in concrete columns, and second-order ($P-\Delta$) effects that influence stiffness and long-term alignment (Chen and Lui, 2005).

3.1.3 Shear Walls and Connections

Shear walls provide lateral stiffness and control drift under wind or minor seismic actions. Although low-rise buildings generally experience limited lateral demand, serviceability drift limits ensure crack control and occupant comfort. Connections—whether welded, bolted, or monolithic—are critical in maintaining structural integrity and stiffness continuity, particularly in steel and composite frames (Segui, 2013).

3.2 Material Systems

3.2.1 Reinforced Concrete

Reinforced concrete (RC) remains the most prevalent material system in low-rise construction due to durability, availability, and cost efficiency. Serviceability assessment in RC frames primarily addresses deflection, cracking, creep, and shrinkage effects. Long-term deflection prediction models are incorporated in codes such as American Concrete Institute (ACI 318), which provides modification factors for sustained loads (ACI, 2019). Crack width control is particularly significant to ensure durability and corrosion protection.

3.2.2 Structural Steel

Structural steel frames offer high strength-to-weight ratios and rapid construction advantages. In low-rise buildings, steel framing performance under service loads is governed by elastic deflection, vibration sensitivity, and local buckling stability. Design provisions such as those in American Institute of Steel Construction (AISC 360) specify serviceability deflection limits and stiffness requirements (AISC, 2016). Steel's elastic behavior simplifies service-level analysis but necessitates careful vibration control.

3.2.3 Composite Systems

Composite framing systems integrate steel and concrete to optimize stiffness and strength. Steel beams with concrete slabs connected via shear studs enhance flexural rigidity and reduce deflections under service loads. Composite action also improves vibration performance and load distribution efficiency. Design methodologies are addressed in European Committee for Standardization (Eurocode 4), which provides serviceability verification procedures for composite members (EN 1994-1-1, 2004).

3.2.4 Timber and Engineered Wood

Timber and engineered wood products, such as glulam and cross-laminated timber (CLT), are increasingly used in sustainable low-rise construction. Serviceability concerns in timber systems include creep deformation, moisture-induced swelling or shrinkage, and floor vibration. Due to lower modulus of elasticity compared to steel and concrete,

deflection control often governs design (Gere and Goodno, 2012).

3.3 Load Path and Typical Service Load Scenarios

3.3.1 Dead Load Distribution

Dead loads consist of self-weight of structural members and permanent fixtures. In low-rise buildings, dead load distribution follows a vertical load path from slabs to beams, beams to columns, and columns to foundations. Accurate estimation of dead loads is essential for predicting long-term deflection, especially in reinforced concrete systems where sustained loading influences creep behavior (Neville, 2011).

3.3.2 Live Load Variations

Live loads represent occupancy-induced and movable loads, varying according to building function. Residential buildings typically experience lower live loads compared to commercial structures. Serviceability checks use characteristic live loads defined in standards such as American Society of Civil Engineers (ASCE 7), often reduced through combination factors when assessing long-term performance (ASCE, 2022). Variability in live load intensity directly affects deflection and vibration assessment.

3.3.3 Environmental Load Considerations (Wind and Temperature)

Environmental loads, including wind and thermal effects, influence service-level behavior. In low-rise buildings, wind loads primarily induce lateral deflection and minor drift, while temperature variations cause expansion and contraction stresses, particularly in steel and composite systems. Eurocode provisions outline serviceability drift limits and thermal action considerations to prevent cracking and joint distress (EN 1991-1-4, 2005). Proper evaluation of these actions ensures structural durability and occupant comfort without approaching ultimate capacity limits.

4. PERFORMANCE ASSESSMENT CRITERIA

4.1 Serviceability Limits

Serviceability limit states (SLS) govern the functional performance of structural framing elements under routine operating conditions. Unlike ultimate limit states, which address collapse prevention, SLS criteria ensure usability, comfort, aesthetic acceptability, and durability throughout the design life. For low-rise buildings, serviceability considerations frequently control member sizing due to span limitations and stiffness requirements (MacGregor and Wight, 2012).

4.1.1 Deflection

Deflection control is one of the primary serviceability criteria in beams and slabs. Excessive vertical deflection may

cause cracking of partitions, misalignment of finishes, and ponding effects on roofs. Design codes prescribe span-to-depth limits or explicit deflection limits, such as those provided in American Concrete Institute (ACI 318), which incorporates modification factors for long-term deflection due to sustained loads (ACI, 2019). In steel structures, elastic deflection limits are typically expressed as span/250 or span/360 depending on occupancy (Segui, 2013). Accurate prediction requires consideration of cracked section stiffness in reinforced concrete and composite action effects where applicable.

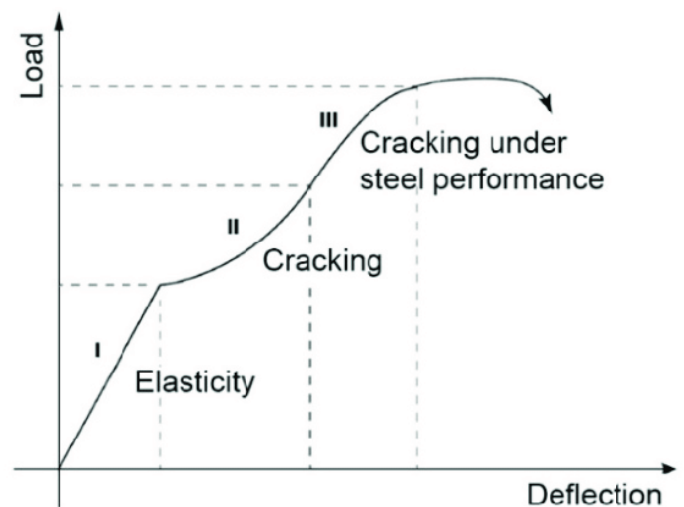


Figure-1: Typical Load-Deflection Behaviour of RC Beam

4.1.2 Vibration

Vibration performance is critical for occupant comfort, particularly in lightweight steel or timber floor systems. Service-level vibrations are influenced by floor stiffness, damping ratio, and fundamental natural frequency. Guidance from American Institute of Steel Construction (AISC Design Guide 11) provides evaluation methods based on acceleration limits and frequency criteria (Murray, Allen and Ungar, 2016). In low-rise residential buildings, vibration rarely leads to structural damage but may produce perceptible discomfort, necessitating stiffness enhancement or damping measures.

4.1.3 Cracking

Crack control in reinforced concrete members is essential to maintain durability and aesthetic performance. Service-level tensile stresses induce flexural cracks, whose width depends on reinforcement ratio, bar spacing, and concrete cover. Excessive cracking can accelerate reinforcement corrosion. Eurocode 2, issued by European Committee for Standardization, specifies maximum allowable crack widths under service loads (EN 1992-1-1, 2004). Proper crack control ensures structural integrity without over-conservative reinforcement provision.

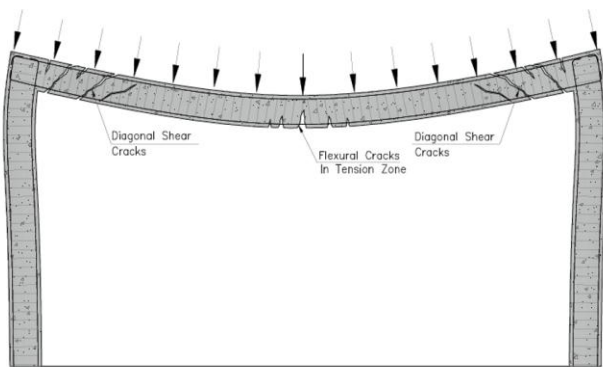


Figure-2: Crack Pattern in RC Beams under Load

4.2 Strength and Safety Margins

Although this review focuses on service loads, strength verification remains indirectly relevant because service-level performance must not compromise ultimate capacity.

4.2.1 Load-Resistance Factors

Modern structural design adopts a limit state philosophy based on load and resistance factor design (LRFD). Service loads are combined with appropriate partial safety factors to ensure reliability. The framework outlined in American Society of Civil Engineers (ASCE 7) differentiates between service-level and strength-level load combinations (ASCE, 2022). Reliability-based calibration of load factors ensures adequate safety margins while maintaining economic efficiency (Nowak and Collins, 2012).

4.2.2 Interaction Formulas

Columns and beam-columns in low-rise buildings frequently experience combined axial load and bending. Interaction diagrams or equations are used to verify safety under combined stress states. For steel members, the interaction provisions in American Institute of Steel Construction (AISC 360) account for stability effects and second-order behavior (AISC, 2016). In reinforced concrete columns, moment-axial force interaction curves ensure compatibility between service and ultimate performance demands.

4.3 Durability Considerations Under Service Loads

Long-term structural performance is strongly influenced by time-dependent and environmental effects that manifest under sustained service loading.

4.3.1 Fatigue

Fatigue refers to progressive material degradation under repeated cyclic loading. While more critical in bridges and industrial structures, fatigue may influence steel framing elements subjected to repetitive occupancy or machinery loads. Fatigue evaluation methods consider stress range and

number of cycles, as outlined in international steel design standards (Fisher et al., 1998). In low-rise buildings, fatigue generally remains within elastic limits but warrants assessment in specialized applications.

4.3.2 Creep and Shrinkage Effects

In reinforced concrete members, creep and shrinkage significantly affect long-term deflection and stress redistribution. Sustained service loads increase curvature over time due to creep, while shrinkage induces additional tensile stresses and cracking. Predictive models incorporated in ACI and Eurocode provisions assist in estimating time-dependent deformations (Neville, 2011). Accurate consideration of these effects is essential for maintaining serviceability throughout the structure's lifespan.

4.3.3 Corrosion Impacts

Corrosion of reinforcement or steel members reduces cross-sectional area and stiffness, thereby influencing service-level performance before ultimate failure occurs. Environmental exposure conditions, crack width, and protective measures determine corrosion progression. Durability design recommendations in Bureau of Indian Standards (IS 456) emphasize cover requirements and crack width control to mitigate corrosion risks (BIS, 2000). Preventive strategies enhance structural longevity under service conditions.

4.4 Design Codes and Standards Review

Comparative analysis of international codes reveals variations in serviceability criteria and safety philosophies. Indian standards (IS 456 and IS 800) adopt empirical span-to-depth ratios and crack control guidelines. Eurocodes apply partial safety factors and explicit deformation checks within a unified limit state framework (EN 1990, 2002). ACI 318 emphasizes deflection multipliers and crack control reinforcement, while ASCE 7 provides load combinations for both service and strength levels. Differences arise in load factors, deflection limits, and vibration assessment procedures, reflecting regional calibration to environmental and construction practices. Such comparative evaluation highlights the need for harmonized performance-based approaches, particularly for low-rise buildings where serviceability often governs design decisions.

5. LITERATURE REVIEW

5.1 Performance Assessment in Reinforced Concrete Frames

Reinforced concrete (RC) frames have been extensively investigated with respect to serviceability behaviour, particularly deflection control, crack development, and long-term deformation. The majority of studies indicate that service load performance is strongly influenced by material nonlinearity and time-dependent effects, even when stresses

remain within elastic limits (Nilson, Darwin and Dolan, 2010).

5.1.1 Experimental Studies

Experimental investigations on RC beams and frames typically involve simply supported or continuous beam specimens subjected to sustained gravity loading to simulate service conditions. Instrumentation commonly includes dial gauges or LVDTs for mid-span deflection measurement and crack-width gauges for monitoring flexural cracking. Long-term tests often incorporate sustained load application over months to evaluate creep-induced deflection amplification. Results consistently demonstrate that actual deflections frequently exceed short-term elastic predictions due to creep and tension stiffening degradation (Branson, 1977). Crack spacing and width are observed to correlate with reinforcement ratio and bar diameter, confirming the importance of reinforcement detailing in service performance.

5.1.2 Numerical and Analytical Models

Analytical approaches initially relied on effective moment of inertia formulations to approximate cracked section stiffness. Subsequently, finite element modelling (FEM) techniques have enabled nonlinear material modelling, incorporating concrete cracking, bond-slip behaviour, and time-dependent creep-shrinkage effects. Parametric studies have examined span-to-depth ratios, reinforcement percentages, and loading duration to quantify their impact on serviceability. Advanced nonlinear simulations show improved accuracy in long-term deflection prediction compared to simplified code-based multipliers (Gilbert, 2010).

5.1.3 Key Observations and Trends

The literature indicates that reinforcement ratio, span-to-depth ratio, sustained load percentage, and environmental exposure conditions are the dominant influencing parameters. Higher reinforcement ratios reduce crack width but may not proportionally decrease long-term deflection due to creep effects. Increasing span-to-depth ratio significantly amplifies service-level deflection, particularly in lightly reinforced slabs. Recent trends emphasize performance-based serviceability assessment integrating probabilistic approaches for more realistic prediction of long-term behaviour (Bažant and Jirásek, 2018).

5.2 Performance Assessment in Steel Framed Systems

Steel frames generally exhibit linear elastic behaviour under service loads, simplifying analytical prediction; however, vibration sensitivity and stability remain critical concerns in low-rise applications.

5.2.1 Experimental Investigations

Experimental research on steel beams and beam-columns under service-level loads primarily evaluates elastic deflection, lateral-torsional buckling initiation, and vibration response. Laboratory testing typically employs monotonic loading within elastic limits, combined with dynamic excitation tests to determine natural frequencies and damping ratios. Observations confirm that serviceability is rarely governed by yielding but by excessive deflection or perceptible vibration in lightweight floor systems (Trahair et al., 2008).

5.2.2 Analytical and Numerical Approaches

Analytical models for steel framing rely on elastic beam theory combined with stability checks for local and global buckling. Numerical approaches incorporate geometric nonlinearity to capture second-order ($P-\Delta$) effects in slender columns. Vibration analyses are conducted using modal superposition methods or finite element eigenvalue analysis to determine fundamental frequency limits for occupant comfort (Chen and Lui, 2005). These approaches enable accurate prediction of service-level deformation without resorting to complex material models.

5.3 Composite Framing Performance

Composite systems combine structural steel beams with reinforced concrete slabs to enhance stiffness and load-carrying capacity.

5.3.1 Concrete-Steel Hybrid Elements

Experimental studies demonstrate that shear connectors enable effective composite action, significantly reducing deflection compared to non-composite steel beams. Service load testing indicates improved vibration performance and crack control due to increased flexural rigidity (Johnson, 2018).

5.3.2 Numerical Performance Studies

Finite element simulations of composite beams incorporate slip modelling at the steel-concrete interface to assess partial interaction effects. Parametric analyses show that connector spacing, slab thickness, and steel beam stiffness are critical variables affecting serviceability response. Long-term performance models also integrate creep of the concrete slab, which may reduce composite stiffness over time.

5.3.3 Research Gaps

Despite substantial research, limited long-term field monitoring data are available for low-rise composite frames. Furthermore, probabilistic serviceability evaluation and sustainability-driven material optimization remain underexplored areas.

5.4 Timber and Other Emerging Material Frames

5.4.1 Overview of Literature

Timber framing, including engineered wood products such as glulam and CLT, has gained prominence in sustainable low-rise construction. Research primarily focuses on serviceability due to lower modulus of elasticity relative to steel and concrete (Gere and Goodno, 2012).

5.4.2 Serviceability Evaluations

Studies emphasize creep deformation under sustained loads, moisture-induced dimensional changes, and vibration performance of lightweight timber floors. Experimental testing reveals that long-term creep coefficients in timber may significantly influence deflection beyond initial elastic predictions. Dynamic analyses indicate that timber floors require frequency checks to satisfy comfort criteria.

5.4.3 Identified Challenges

Major challenges include variability in material properties, moisture sensitivity, and limited predictive models for long-term serviceability. Standardized performance assessment methodologies are still evolving compared to concrete and steel systems.

5.5 Comparative Synthesis

5.5.1 Cross-Material Performance Trends

Comparative evaluation across materials reveals that reinforced concrete frames are primarily governed by creep-induced deflection and crack control, steel systems by vibration and elastic deflection, composite systems by interface behaviour and long-term interaction effects, and timber systems by creep and moisture sensitivity. Serviceability often governs design in low-rise buildings irrespective of material type.

5.5.2 Synthesis Through Metrics and Meta-Analysis

Several studies compile deflection ratios, crack width limits, and vibration frequency thresholds to compare performance benchmarks. Where meta-analytical data are available, pooled results indicate that span-to-depth ratio and stiffness-to-mass ratio are universal parameters influencing service-level response across material systems. However, variability in testing conditions limits direct quantitative comparison, emphasizing the need for standardized evaluation frameworks.

6. CONCLUSION

This review critically synthesizes existing literature on the performance assessment of structural framing elements in low-rise buildings under service loads. The analysis demonstrates that serviceability limit states frequently

govern the design and long-term functionality of beams, slabs, columns, shear walls, and connections across reinforced concrete, structural steel, composite, and timber systems. Reinforced concrete frames are predominantly influenced by creep, shrinkage, and cracking behaviour, which significantly affect long-term deflection predictions. Steel framing systems generally satisfy strength requirements under service loads but are often controlled by vibration performance and elastic deflection limits. Composite systems exhibit enhanced stiffness and improved service performance; however, long-term interaction effects and partial shear connection behaviour remain important considerations. Timber and engineered wood frames, while sustainable and efficient for low-rise construction, require rigorous evaluation of creep deformation and vibration sensitivity.

Across material systems, span-to-depth ratio, stiffness characteristics, reinforcement detailing, and sustained load levels emerge as dominant parameters influencing service-level performance. Comparative evaluation of international standards reveals variations in deflection limits, crack control provisions, and load combination philosophies, highlighting the need for harmonized performance-based frameworks. Although analytical and numerical modelling techniques have advanced considerably, discrepancies remain between simplified code-based predictions and observed long-term behaviour. Overall, this review underscores the importance of integrating experimental evidence, refined modelling approaches, and durability considerations to ensure reliable service load performance in low-rise structural systems.

7. LIMITATIONS OF THE REVIEW

This review is limited to published peer-reviewed studies and standard design provisions, potentially excluding relevant industry reports or unpublished field monitoring data. The analysis emphasizes service-level behaviour and does not extensively address ultimate limit state interactions unless directly related to serviceability. Variability in experimental setups, material properties, environmental conditions, and analytical assumptions across studies restricts direct quantitative comparison. Furthermore, meta-analytical statistical synthesis was constrained by inconsistent reporting of performance metrics in the reviewed literature.

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