A REVIEW OF PARAMETRIC STUDY ON THE EFFECT OF BUILDING PLAN GEOMETRY ON DYNAMIC RESPONSE OF RC STRUCTURES MODELED IN ETABS

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Abstract - *The dynamic response of reinforced concrete (RC) buildings is significantly influenced by plan geometry, particularly under seismic excitation. Variations in geometric configuration alter stiffness distribution, mass eccentricity, torsional behavior, and modal characteristics, thereby affecting overall structural performance. In recent years, parametric studies using ETABS have become a dominant approach for evaluating the influence of plan irregularities on dynamic behavior. This review critically synthesizes existing research on the effect of building plan geometry—including regular and irregular configurations, aspect ratio variations, re-entrant corners, setbacks, and plan discontinuities—on key dynamic response parameters such as natural period, mode shapes, base shear, story displacement, inter-storey drift, and torsional irregularity.*

The paper systematically categorizes prior studies based on geometry type, modeling assumptions, seismic analysis method (response spectrum and time-history analysis), and reported performance indicators. Trends across the literature indicate that plan irregularities consistently amplify torsional effects and drift concentration, while aspect ratio variations significantly modify fundamental time periods and mode participation factors. However, inconsistencies arise due to differences in seismic codes, modeling strategies, and boundary conditions.

This review identifies critical research gaps, including the need for standardized parametric frameworks and integration of soil–structure interaction effects. The findings provide a consolidated reference for researchers and practicing engineers engaged in seismic analysis and design optimization of RC structures.

***Key Words*: Building Plan Geometry, Dynamic Response, Reinforced Concrete Structures, ETABS Modeling, Seismic Analysis, Parametric Study**

1. INTRODUCTION

1.1 Background of RC Structural Analysis in Earthquake Engineering

Reinforced concrete (RC) structures constitute a major proportion of urban building stock worldwide due to their durability, constructability, and economic efficiency. In seismic regions, the structural safety of RC buildings is governed by their ability to dissipate energy through controlled inelastic behavior while maintaining overall stability. Classical earthquake engineering principles establish that structural response depends primarily on mass distribution, stiffness characteristics, damping properties, and the dynamic properties of ground motion (Chopra, 2017). Modern seismic codes such as Bureau of Indian Standards through IS 1893 (BIS, 2016) and guidelines from American Society of Civil Engineers (ASCE 7-16) emphasize dynamic analysis for multi-storey RC buildings, particularly when irregularities are present.

Advances in finite element modelling have significantly enhanced the precision of structural analysis. Software platforms such as ETABS allow detailed modelling of three-dimensional RC frames, incorporating nonlinear material behavior, modal analysis, response spectrum analysis, and time-history analysis. As a result, parametric studies evaluating seismic performance under varying geometric configurations have become increasingly prevalent.

1.2 Importance of Dynamic Response Evaluation

Dynamic response evaluation is central to seismic performance assessment because earthquake loads are inertia-driven and time-dependent. Unlike static gravity loads, seismic forces arise from structural acceleration, which is directly related to mass and modal properties (Clough and Penzien, 2003). Parameters such as natural period, mode shapes, modal participation factors, base shear, and inter-storey drift determine whether a structure meets serviceability and ultimate limit state criteria.

Irregular distributions of stiffness and mass alter modal coupling and torsional amplification, leading to localized drift concentrations and potential soft-storey mechanisms (Paulay and Priestley, 1992). Research consistently shows that even moderate plan asymmetry can significantly increase torsional demands, thereby affecting column shear forces and beam–column joint behavior (Tso and Moghadam, 1998). Therefore, dynamic analysis is indispensable when investigating the influence of geometric variations in RC buildings.

1.3 Relevance of Plan Geometry in Structural Behavior

1.3.1 Regularity and Symmetry

Plan geometry directly governs the spatial distribution of stiffness and mass. Regular and symmetric plans typically exhibit uniform lateral load distribution and predictable modal behavior. In contrast, asymmetric or irregular plans introduce eccentricity between the center of mass and center of rigidity, generating torsional response under seismic excitation (Chopra, 2017). Codes such as IS 1893 classify such configurations as torsionally irregular when specified drift limits are exceeded (BIS, 2016).

1.3.2 Aspect Ratio and Plan Dimensions

The ratio of plan length to width significantly affects lateral stiffness in orthogonal directions. Buildings with elongated plans often display distinct modal participation in longitudinal and transverse directions, altering fundamental periods and response spectrum demand (Goel and Chopra, 1997). Parametric investigations indicate that increasing aspect ratio may amplify displacement demand in the weaker direction due to reduced lateral stiffness.

1.3.3 Torsional Irregularity, Setbacks, and Openings

Re-entrant corners, setbacks, and large plan openings create stress concentration zones and discontinuities in load transfer paths. These geometric features intensify torsional effects and modify dynamic characteristics (Moehle, 2014). Vertical setbacks can further introduce stiffness irregularity across storeys, influencing higher-mode participation and drift distribution patterns.

1.4 Motivation for the Review

Although numerous parametric studies have examined geometric irregularities in RC buildings, the findings remain fragmented. Differences in modeling assumptions, seismic input selection, damping ratios, and code provisions often yield inconsistent conclusions regarding the magnitude of dynamic amplification. Some studies emphasize the dominance of torsional response, while others highlight drift concentration or base shear variation as the primary concern.

Moreover, comparative synthesis across different plan configurations—such as rectangular, L-shaped, T-shaped, and U-shaped buildings—has not been systematically consolidated. A comprehensive review is therefore necessary to integrate existing findings, identify methodological limitations, and clarify consensus trends in the literature.

1.5 Objective and Scope of the Review

The primary objective of this review is to critically synthesize parametric studies investigating the effect of building plan geometry on the dynamic response of RC structures. The review focuses on key geometric parameters including plan regularity, aspect ratio, torsional irregularity, re-entrant corners, vertical setbacks, and plan discontinuities such as openings.

The scope is restricted to numerical studies that evaluate seismic response metrics such as natural period, base shear, storey displacement, inter-storey drift, and torsional response parameters. Emphasis is placed on multi-storey framed RC buildings analyzed under response spectrum and time-history methods consistent with prevailing seismic codes.

1.6 Rationale for Focusing on Studies Using ETABS

The selection of ETABS as a focal modelling platform is justified by its widespread acceptance in both academic research and professional practice. Developed specifically for building systems, ETABS integrates three-dimensional modelling, dynamic analysis capabilities, code-based load generation, and detailed output interpretation. Its ability to simulate modal participation, diaphragm behavior, and accidental eccentricity makes it particularly suitable for parametric evaluation of plan irregularities.

Furthermore, a significant proportion of published parametric studies on RC buildings employ ETABS as the primary analysis tool, enabling meaningful comparison of modelling approaches and outcomes. Concentrating on ETABS-based studies enhances consistency in methodological evaluation and facilitates clearer synthesis of trends across the literature.

2. REVIEW METHODOLOGY

A rigorous and transparent methodology is essential in review-based research to ensure reproducibility, minimize selection bias, and enhance academic credibility. The present review adopts a structured literature survey approach consistent with systematic review principles commonly used in engineering research. The procedure includes database searching, screening based on predefined criteria, and thematic categorization of relevant studies. The methodological framework is informed by established review protocols emphasizing clarity in identification, screening, eligibility, and inclusion stages (Kitchenham, 2004; Tranfield, Denyer and Smart, 2003).

2.1 Search Strategy

2.1.1 Databases Consulted

The literature survey was conducted using major indexed academic databases to ensure quality and reliability of sources. The primary databases included Scopus, Web of Science, and Google Scholar. These platforms were selected due to their extensive coverage of peer-reviewed journals in structural engineering, earthquake engineering, and computational modelling.

Scopus and Web of Science were prioritized for sourcing high-impact SCI/SCIE-indexed journal articles, while Google Scholar was used as a supplementary tool to identify conference papers and citation trails that supported thematic continuity.

2.1.2 Keywords and Boolean Combinations

Search strings were formulated to capture studies focusing on geometric irregularities and dynamic response of RC buildings. Core keywords included: "building plan geometry", "RC structures", "dynamic response", "seismic analysis", "parametric study", and "ETABS modelling".

Boolean operators (AND, OR) were systematically applied to refine search outputs. For example:

- "RC buildings" AND "plan irregularity" AND "dynamic analysis"
- "ETABS" AND "parametric study" AND "seismic response"
- "aspect ratio" OR "torsional irregularity" AND "reinforced concrete"

This structured search ensured comprehensive retrieval of relevant studies while limiting unrelated structural modelling research.

2.2 Inclusion and Exclusion Criteria

2.2.1 Time Frame and Publication Quality

To capture contemporary analytical practices and code-based design evolution, the review considered studies published between 2000 and 2025. This time frame reflects the period during which advanced finite element software and modern seismic codes became widely adopted.

Only peer-reviewed journal articles indexed in SCI/SCIE databases were included to ensure methodological robustness and academic credibility. Conference papers were considered selectively when they provided foundational or widely cited contributions.

2.2.2 Study Type and Analytical Scope

The review included studies that performed parametric investigations of building plan geometry using numerical modelling techniques, particularly finite element-based software such as ETABS. Research addressing response spectrum analysis, time-history analysis, or ambient vibration analysis of multi-storey RC buildings was retained.

Studies were excluded if they:

- Focused solely on material-level behaviour without global dynamic analysis,
- Examined non-RC structural systems exclusively (e.g., steel-only systems),
- Did not evaluate geometric parameters explicitly, or
- Provided purely theoretical derivations without modelling validation.

These criteria ensured thematic consistency with the objectives of the review.

2.3 Data Extraction and Categorization

Following screening, relevant studies were systematically analysed and categorized to enable comparative synthesis.

2.3.1 Type of Study

Each article was classified as numerical, experimental, or hybrid (combined analytical–experimental). The majority of studies employed three-dimensional finite element modelling, reflecting the dominance of computational parametric research in this domain. Experimental investigations were comparatively limited due to practical constraints in full-scale seismic testing.

2.3.2 Building Typology

Studies were further categorized based on structural height classification:

- Low-rise (1–5 storeys)
- Mid-rise (6–15 storeys)
- High-rise (>15 storeys)

Building height influences modal participation and higher-mode effects, making typology classification essential for interpreting dynamic response variations (Chopra, 2017).

2.3.3 Plan Geometry Parameters Evaluated

The extracted data included the type of geometric irregularity assessed, such as:

- Symmetric vs asymmetric plans
- L-, T-, U-, and H-shaped configurations
- Aspect ratio variations
- Re-entrant corners
- Setbacks and plan discontinuities

- Presence of openings

This categorization enabled comparative mapping of geometry-specific effects on natural period, base shear, storey drift, and torsional response.

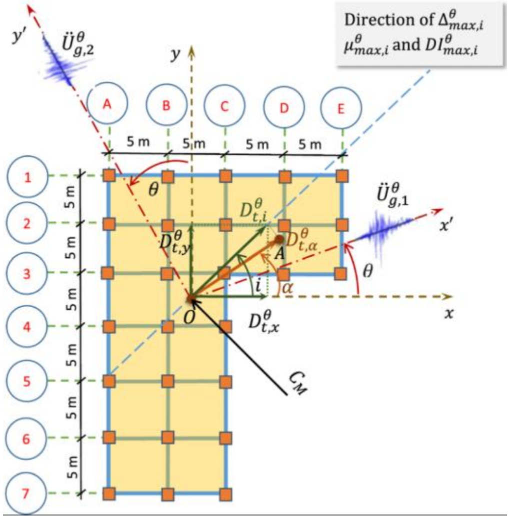

Figure-1: Re-entrant corners

2.3.4 Seismic Codes and Ground Motion Inputs

The review also documented the seismic codes referenced (e.g., IS 1893, ASCE 7, Eurocode 8) and the type of ground motion input adopted (design response spectrum or recorded accelerograms). Variations in code provisions and damping assumptions significantly influence reported response parameters, necessitating explicit classification during synthesis (Paulay and Priestley, 1992).

3. FUNDAMENTAL CONCEPTS

This section outlines the theoretical foundations necessary to understand how building plan geometry influences the dynamic behaviour of reinforced concrete (RC) structures. The discussion is limited to established principles in structural dynamics and seismic analysis, without introducing original analytical results.

3.1 Dynamic Response of RC Structures

The seismic behaviour of RC buildings is fundamentally governed by structural dynamics. When subjected to earthquake excitation, inertia forces are generated due to ground acceleration, and the resulting structural response depends on mass, stiffness, and damping characteristics. The dynamic equilibrium of a multi-degree-of-freedom (MDOF) system can be expressed through matrix formulations involving mass, damping, and stiffness matrices, which collectively define modal characteristics (Chopra, 2017).

3.1.1 Natural Frequencies and Mode Shapes

Natural frequencies represent the inherent vibration characteristics of a structure when disturbed from equilibrium. Each frequency corresponds to a specific mode shape that describes deformation patterns. In multi-storey RC buildings, the first few modes typically dominate seismic response, particularly in regular structures. However, irregular plan configurations may activate torsional modes and higher-mode participation, significantly altering displacement and drift distribution (Clough and Penzien, 2003).

The fundamental time period, which is the inverse of the first natural frequency, is particularly important because seismic demand from response spectra is strongly period-dependent. Variations in stiffness and mass distribution—often caused by geometric irregularities—directly influence modal properties.

3.1.2 Response Spectrum and Time-History Analysis

Response spectrum analysis is a linear dynamic procedure widely adopted in seismic design. It estimates peak structural responses by combining modal contributions using predefined design spectra derived from seismic codes. This method is computationally efficient and suitable for parametric studies of multiple geometric configurations (Moehle, 2014).

Time-history analysis, in contrast, involves step-by-step integration of the dynamic equilibrium equation under recorded or simulated ground motions. It captures temporal variations in response and is capable of representing nonlinear behaviour when required. Although computationally more intensive, it provides detailed insight into torsional amplification and higher-mode effects in irregular buildings.

3.2 Building Plan Geometry Characteristics

Building plan geometry significantly influences lateral load-resisting behaviour by modifying stiffness and mass distribution across the structure. Geometric configuration determines how seismic forces are transferred through beams, columns, and diaphragms to the foundation.

3.2.1 Regular versus Irregular Configurations

A building is considered plan-regular when its stiffness and mass are symmetrically distributed, minimizing eccentricity between the centre of mass and centre of rigidity. Seismic design codes define torsional irregularity based on drift ratios and eccentricity limits; for instance, IS 1893 (BIS, 2016) specifies threshold values for identifying irregular configurations.

Irregular buildings, such as L-shaped, T-shaped, or U-shaped plans, exhibit inherent eccentricity that induces torsional moments during seismic excitation. These torsional effects increase lateral displacement demand in peripheral elements and may lead to stress concentration.

3.2.2 Geometric Parameters

Several geometric parameters are critical in evaluating dynamic response:

Aspect Ratio: The ratio of plan length to width affects directional stiffness. Elongated buildings tend to have differing fundamental periods in orthogonal directions, influencing modal dominance.

Symmetry: Symmetric layouts generally produce uniform drift patterns, while asymmetric layouts amplify torsion.

Openings: Large floor openings or atriums alter diaphragm stiffness and modify load paths.

Setbacks: Sudden reductions in plan area at higher storeys create stiffness discontinuities.

Re-entrant Corners: Sharp internal corners concentrate stresses and induce localized torsional effects.

These features collectively modify global stiffness matrices and mass eccentricity, directly influencing modal characteristics and seismic response (Paulay and Priestley, 1992).

3.2.3 Influence on Stiffness and Mass Distribution

Plan irregularities alter the distribution of lateral stiffness among structural elements. When stiffness is unevenly distributed, the centre of rigidity shifts relative to the centre of mass, generating accidental or inherent torsion. This imbalance increases rotation about the vertical axis and causes differential displacement across the floor diaphragm. Consequently, structural members located at extreme edges experience amplified forces and drift demands. Such redistribution effects are especially critical in multi-storey RC frames where diaphragm rigidity assumptions significantly influence dynamic behaviour.

3.3 Modelling RC Structures in ETABS

Finite element modelling plays a central role in evaluating the dynamic characteristics of RC buildings. ETABS is a widely adopted structural analysis platform specifically developed for building systems. It integrates modelling, analysis, and design functionalities within a unified environment, enabling efficient simulation of multi-storey RC frames.

3.3.1 ETABS Capabilities in Dynamic Analysis

ETABS facilitates three-dimensional modelling of beams, columns, slabs, shear walls, and diaphragms. It automatically generates mass matrices based on assigned loads and material properties, allowing accurate computation of modal properties. The software also incorporates code-based seismic load definitions, damping assumptions, and accidental eccentricity considerations.

Its parametric modelling flexibility makes it particularly suitable for evaluating multiple plan configurations under identical loading conditions, thereby supporting comparative studies of geometric variations.

3.3.2 Modal, Response Spectrum, and Time-History Procedures

ETABS performs eigenvalue analysis to determine natural frequencies and mode shapes. Modal participation factors and cumulative mass participation ratios are automatically calculated, enabling verification of dynamic completeness.

For response spectrum analysis, ETABS applies modal superposition methods such as SRSS and CQC to combine modal effects. In time-history analysis, the software conducts direct integration using user-defined ground motion records. These capabilities allow detailed evaluation of displacement, drift, base shear, torsional response, and storey forces, making ETABS a preferred tool for parametric investigation of plan geometry effects.

4. LITERATURE REVIEW

This section synthesizes prior research on the influence of building plan geometry on the dynamic response of reinforced concrete (RC) structures. The review is organized thematically to enable systematic comparison of findings across different geometric parameters and modelling approaches.

4.1 Early Studies on Geometry and Dynamic Behaviour

4.1.1 Pioneering Work and Foundational Concepts

Early investigations into the seismic behaviour of asymmetric and irregular buildings established the theoretical link between plan geometry and torsional response. Analytical studies demonstrated that eccentricity between the centre of mass and centre of rigidity leads to coupled translational–torsional vibration modes, significantly increasing edge displacements (Tso and Moghadam, 1998). These foundational works emphasized that even slight plan asymmetry can amplify seismic demand beyond that predicted by simplified static methods.

Subsequent analytical research incorporated modal superposition techniques to quantify dynamic amplification in multi-storey frames, highlighting the importance of higher-mode effects in irregular buildings (Goel and Chopra, 1997).

4.1.2 Key Findings and Limitations

While early studies established conceptual clarity, many relied on simplified lumped-mass models and linear elastic assumptions. Material nonlinearity, diaphragm flexibility, and soil–structure interaction were often neglected.

4.2 Plan Regularity versus Irregularity

4.2.1 Regular Geometry Studies

Research on regular rectangular buildings generally reports predictable modal participation and uniform drift distribution. The fundamental mode often dominates response, with minimal torsional coupling under symmetric loading. Such configurations are frequently used as benchmark models for comparison against irregular geometries (Chopra, 2017).

These studies provide baseline dynamic characteristics, enabling quantification of amplification effects introduced by irregular plans.

4.2.2 Irregular Plan Geometries

Irregular plan configurations—including L-, T-, U-, and H-shaped layouts—have been widely examined in parametric analyses. Studies consistently indicate increased torsional rotation, drift concentration at re-entrant corners, and uneven force distribution across columns (Moehle, 2014). Offsets and plan asymmetry shift the centre of rigidity, generating amplified shear forces at extreme edges.

Re-entrant corners, in particular, create stress concentration zones and discontinuities in load paths. Comparative simulations reveal that such buildings often exhibit larger inter-storey drifts than their regular counterparts under identical seismic input.

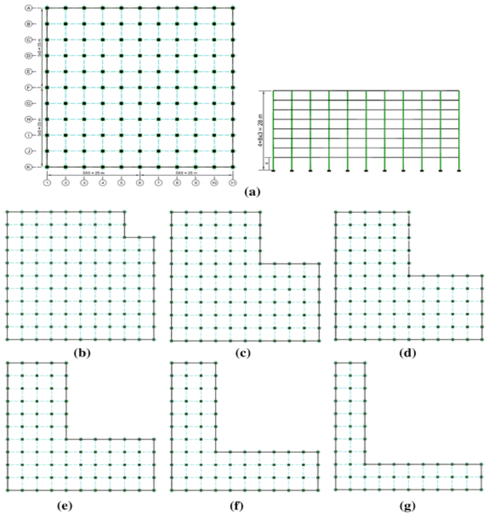

Figure-2: Irregular Plan Geometries

4.2.3 Summary Comparisons

Across multiple investigations, irregular buildings demonstrate greater dynamic amplification factors and higher torsional irregularity indices than regular configurations. However, the magnitude of amplification varies depending on stiffness modelling assumptions, diaphragm rigidity, and selected seismic spectra.

4.3 Influence of Aspect Ratio and Mass Distribution

4.3.1 Studies Investigating Length-to-Width (l/b) Effects

The aspect ratio (length-to-width ratio) significantly influences directional stiffness. Parametric studies varying l/b ratios show that elongated buildings tend to exhibit increased flexibility along the weaker axis, resulting in larger lateral displacements and altered modal participation patterns (Reddy and Jangid, 2012).

Changes in plan proportions also affect base shear distribution, particularly when mass irregularities are present.

4.3.2 Mode Shape Changes and Fundamental Period Shifts

Increasing aspect ratio generally lengthens the fundamental period in the weaker direction due to reduced lateral stiffness. This shift may move the structure closer to peak spectral acceleration regions, thereby increasing seismic demand. Several studies report higher participation of torsional and higher modes in buildings with significant mass eccentricity, indicating complex modal coupling effects.

4.4 Effect of Openings and Plan Discontinuities

4.4.1 Large Openings and Courtyard Effects

Large floor openings, atriums, and courtyard-type configurations alter diaphragm action and reduce in-plane stiffness. Analytical models indicate that discontinuities in slab geometry can modify lateral load paths and increase torsional sensitivity (Paulay and Priestley, 1992).

Courtyard buildings often behave similarly to re-entrant corner structures, exhibiting stress concentration at internal edges and increased rotational demand.

4.4.2 Influence on Stiffness and Torsion

Reduction in diaphragm stiffness due to openings can shift the centre of rigidity, intensifying accidental torsion. Studies show that partial diaphragm flexibility increases differential displacement across floor levels, especially in mid- to high-rise RC frames.

4.5 Setbacks and Vertical Irregularities

4.5.1 Plan Setbacks at Multiple Levels

Vertical geometric irregularities such as setbacks create abrupt changes in stiffness and mass distribution along the building height. Research indicates that these discontinuities modify mode shapes and introduce localized drift concentration near setback levels (Khan and Parvez, 2014).

Multi-level setbacks often activate higher-mode effects, increasing shear demand in intermediate storeys.

4.5.2 Impact on Dynamic Amplification and Mode Coupling

Setback buildings exhibit significant mode coupling due to non-uniform stiffness distribution. Dynamic amplification factors in such configurations are typically greater than those in uniform-height structures. Numerical analyses reveal increased sensitivity to ground motion characteristics, particularly near resonance conditions.

4.6 Seismic Response Metrics Reported

4.6.1 Natural Period Shifts

Many studies evaluate changes in fundamental period as a primary indicator of geometric influence. Plan irregularity generally increases flexibility, leading to longer periods compared with regular benchmarks.

4.6.2 Base Shear and Drift Parameters

Base shear, storey displacement, and inter-storey drift are the most commonly reported response parameters. Irregular buildings frequently show uneven drift distribution, with maximum values concentrated at corners or discontinuity zones (Chopra, 2017).

4.6.3 Torsional Response Measures

Torsional irregularity ratios, edge displacement differences, and rotational mode participation are often used to quantify torsional effects. Comparative findings consistently demonstrate that asymmetric plans produce higher torsional amplification than symmetric layouts.

4.7 Parametric Techniques and Sensitivity Analysis

4.7.1 Approaches Used

Parametric studies commonly vary one geometric parameter while holding others constant. Some researchers employ Design of Experiments (DOE) frameworks to systematically explore multi-parameter interactions. Sensitivity plots and regression-based models are occasionally used to establish correlations between geometry and response metrics (Montgomery, 2017).

4.7.2 Common Findings

Sensitivity analyses generally identify torsional eccentricity and aspect ratio as dominant contributors to drift amplification. However, the relative influence of each parameter depends on building height and stiffness configuration.

4.8 Trends in Modelling Practices

4.8.1 Static versus Dynamic Analysis Preferences

Earlier investigations often relied on equivalent static methods for simplicity. However, contemporary research predominantly adopts response spectrum or time-history analysis due to the complex modal behaviour of irregular buildings. Dynamic analysis is widely recognized as essential for capturing torsional coupling and higher-mode effects (Clough and Penzien, 2003).

6.8.2 Use of ETABS Modelling Features

Recent studies frequently employ ETABS for three-dimensional modelling. Common modelling assumptions include rigid diaphragm constraints, lumped mass representation at floor levels, and code-based damping ratios. Mesh density in slab modelling and accidental eccentricity considerations vary across studies, contributing to differences in reported results.

Overall, modelling sophistication has increased over time, yet standardization in parametric frameworks remains limited, reinforcing the need for consolidated review and methodological harmonization.

5. SYNTHESIS OF FINDINGS

This section integrates the reviewed literature to identify overarching patterns, inconsistencies, and methodological limitations in studies examining the influence of building plan geometry on the dynamic response of reinforced concrete (RC) structures. Rather than reiterating individual investigations, the discussion consolidates evidence into thematic conclusions relevant to seismic performance assessment.

5.1 Consensus in the Literature

5.1.1 Geometric Parameters Consistently Affecting Dynamic Behaviour

Across the reviewed studies, several geometric parameters emerge as consistently influential in modifying dynamic response. Plan irregularity—particularly torsional eccentricity—has been widely recognized as a primary driver of amplified rotational response and differential edge displacement (Tso and Moghadam, 1998). Buildings exhibiting re-entrant corners or asymmetric layouts generally demonstrate increased torsional coupling and higher inter-storey drift at peripheral columns.

Aspect ratio (length-to-width ratio) is another parameter repeatedly shown to affect modal characteristics. Elongated plans tend to increase flexibility along the weaker axis, leading to longer fundamental periods and directional amplification effects (Goel and Chopra, 1997). Similarly, vertical setbacks and discontinuities alter stiffness distribution along the height, influencing higher-mode participation.

5.1.2 Generalised Trends Reported

The literature broadly agrees that irregular plan geometries increase seismic demand compared with regular rectangular configurations. Commonly observed trends include:

- Increased torsional rotation in asymmetric buildings.
- Drift concentration near re-entrant corners or setback levels.
- Period elongation associated with reduced lateral stiffness.
- Greater sensitivity to accidental eccentricity in taller structures.

These findings align with fundamental dynamic theory, which links mass–stiffness imbalance to modal coupling and amplified response (Chopra, 2017). Overall, regularity in plan geometry is consistently associated with more predictable and uniform response patterns.

5.2 Conflicting Results

5.2.1 Areas of Disagreement

Despite broad consensus on qualitative trends, quantitative results vary significantly across studies. For example, some investigations report substantial increases in base shear due to irregularity, while others observe marginal differences when dynamic analysis methods are applied. Discrepancies also exist regarding the magnitude of torsional amplification for similar geometric configurations.

In certain parametric studies, aspect ratio variation produced pronounced changes in natural period, whereas other analyses reported minimal impact when stiffness was proportionally adjusted.

5.2.2 Reasons for Variability

Several factors contribute to these inconsistencies. Differences in seismic design codes—such as IS 1893, ASCE 7, or Eurocode 8—introduce variation in response spectra, damping assumptions, and load combinations (Paulay and Priestley, 1992). Ground motion selection in time-history analysis further influences dynamic amplification, especially when resonance effects occur.

Modelling assumptions also vary considerably. Some studies assume rigid diaphragms, while others model semi-rigid behaviour; mass modelling approaches (lumped versus distributed) and boundary conditions differ as well. Furthermore, the choice of modal combination method (SRSS vs. CQC) can alter response estimates. These methodological disparities complicate direct comparison of reported numerical outcomes.

5.3 Critical Observations

5.3.1 Limitations in Existing Literature

A recurring limitation in the literature is the narrow scope of geometric variation considered in individual studies. Many parametric analyses examine only one irregular configuration at a time, limiting generalizability. Additionally, interaction effects between multiple geometric parameters—such as combined aspect ratio change and setback irregularity—are rarely explored systematically.

5.3.2 Limited Sample Diversity

Numerous studies focus on a small number of plan types, often restricted to rectangular, L-shaped, or T-shaped configurations. Broader architectural variations, including complex hybrid layouts, remain underexplored. Moreover, most research considers idealized building models rather than realistic structural systems incorporating nonstructural components or irregular mass distribution.

5.3.3 Lack of Experimental Validation and Tool Dependence

Experimental validation of numerical findings is limited due to practical constraints in large-scale seismic testing. Consequently, the majority of conclusions are derived from computational simulations. Overreliance on a single modelling platform—frequently ETABS—may introduce systematic bias associated with embedded modelling assumptions and default parameters. Comparative studies using alternative finite element platforms are relatively scarce.

In summary, while strong qualitative agreement exists regarding the detrimental influence of plan irregularity on dynamic performance, quantitative variability and methodological limitations highlight the need for standardized parametric frameworks and broader validation approaches.

6. CONCLUSION

This review consolidates existing research on the influence of building plan geometry on the dynamic response of reinforced concrete (RC) structures, with particular emphasis on parametric studies conducted using ETABS. The synthesis of literature demonstrates that geometric configuration plays a decisive role in governing seismic behaviour. Plan irregularities such as asymmetry, re-entrant corners, setbacks, and large openings consistently induce torsional amplification, drift concentration, and uneven force distribution. Aspect ratio variations significantly modify directional stiffness and fundamental time periods, thereby influencing spectral demand and modal participation.

Across studies, regular rectangular configurations exhibit more uniform displacement profiles and reduced torsional sensitivity compared with irregular layouts. Dynamic analysis methods, particularly response spectrum and time-history analysis, are shown to provide more reliable assessment of such effects than equivalent static procedures. However, quantitative differences in reported results highlight the impact of modelling assumptions, seismic code provisions, and ground motion selection.

Overall, the literature establishes a clear qualitative consensus: increased geometric irregularity generally leads to higher seismic vulnerability. Nevertheless, inconsistencies in parametric frameworks and modelling practices limit direct comparability across studies. The findings underscore the necessity for standardized analytical procedures and integrated evaluation of multiple geometric parameters to improve predictive accuracy and support seismic design optimization of RC buildings.

6.1. Limitations of the Review

This review is subject to several limitations. First, it focuses primarily on numerical parametric studies, with limited incorporation of experimental investigations due to their scarcity in the literature. Second, the analysis emphasizes research employing ETABS-based modelling; therefore, findings may reflect software-specific assumptions and default analytical procedures. Third, only peer-reviewed journal articles published within a defined time frame were considered, potentially excluding relevant conference proceedings or regional studies.

Additionally, variations in seismic codes, ground motion records, damping assumptions, and diaphragm modelling across studies restrict precise quantitative comparison. The review synthesizes reported trends rather than re-evaluating raw numerical data, which may mask subtle contextual differences among investigations.

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