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# Eurocode-Based Structural Analysis and Design of a G+5 Reinforced Concrete Residential Building

Karambir[1], Dr. Sudesh Kumari[2]

[1]M.Tech Structural Engineering, Baba Mastnath University, Rohtak
[2]Under the Supervision of HOD, Assistant Professor, BMU, RTK

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## ABSTRACT

**Rapid growth of urban housing has increased the need for medium-rise reinforced concrete buildings that can carry gravity loads while maintaining adequate resistance against wind and earthquake actions. This paper presents a Eurocode-based structural analysis and design methodology for a G+5 reinforced concrete residential building. The study develops permanent, imposed, wind and seismic actions; explains a three-dimensional frame idealisation with rigid floor diaphragm action; applies ultimate and serviceability combinations; and verifies representative beams, columns, slabs, drift and isolated footings. Numerical calculations are presented for beam line load, design base shear, wind base shear, lateral force distribution, beam bending, column axial demand and footing bearing pressure. The proposed building has a 24 m x 16 m regular plan, 3.2 m storey height, C30/37 concrete and B500 reinforcement. Results show that seismic action governs global lateral strength for the adopted site, while gravity load controls beam design and column axial load. The maximum roof displacement of 17.4 mm remains within a practical serviceability range, and a 3.0 m x 3.0 m isolated footing gives a service bearing pressure below the adopted allowable bearing capacity. The paper converts a practical calculation workflow into a publication-style academic format suitable for M.Tech structural engineering work.**

**Keywords: G+5 residential building; Eurocode; reinforced concrete; seismic analysis; wind load; storey drift; beam design; column design; isolated footing; structural serviceability.**

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## INTRODUCTION

Reinforced concrete framed buildings are widely used for residential construction because they offer fire resistance, durability, material availability and flexibility in architectural planning. A G+5 building is neither a very low-rise structure nor a high-rise tower; it is a medium-rise structural system in which both vertical and lateral actions must be treated carefully. Gravity loads govern slab and beam sizing, but wind and seismic forces influence frame stiffness, column moments, storey drift, foundation reactions and non-structural damage.

In many academic design submissions, the main weakness is not the absence of calculations but the absence of a clear load path. Loads are sometimes inserted into software without showing how area loads become line loads, how storey masses create seismic forces, how lateral forces are distributed, and how column reactions are transferred to footings. The present paper addresses this gap by presenting a transparent workflow in which every calculation can be traced to a physical part of the building.

The Eurocode framework is adopted because it gives an integrated route from reliability and load combinations to concrete member design and geotechnical verification. EN 1990 is used for basis of design, EN 1991 for imposed and wind actions, EN 1992 for reinforced concrete design, EN 1997 for geotechnical checks and EN 1998 for earthquake resistance. Although the case study uses assumed academic data, the methodology can be adapted to actual projects after replacing the plan dimensions, site class, wind parameters, soil properties and material grades with project-specific values.

### Building Description and Design Basis

The selected structure is a regular six-storey reinforced concrete residential building consisting of ground plus five upper floors. The building plan is rectangular to limit torsional irregularity and to allow a clear comparison between gravity and lateral load effects. The lateral load-resisting system consists of moment-resisting reinforced concrete frames in both principal directions. Floor slabs are assumed to act as rigid diaphragms, transferring lateral inertia forces to the frames according to their relative stiffness.

| Design item | Adopted value / criterion | Engineering significance |
|---|---|---|
| Building type | G+5 RC residential building | Represents common medium-rise urban housing. |
| Plan dimensions | 24 m x 16 m; bays of 6 m and 4 m | Regular grid improves modelling clarity and reduces torsion. |
| Storey data | Six storeys; 3.2 m storey height; total height 19.2 m | Controls wind exposure, seismic force distribution and drift. |
| Structural system | RC moment-resisting frame with 150 mm slab diaphragm | Provides gravity load path and lateral resistance. |
| Materials | C30/37 concrete and B500 reinforcement | Compatible with EN 1992 strength and ductility design. |
| Soil condition | Medium dense sand; allowable pressure 200 kN/m2 | Used for preliminary isolated footing verification. |
| Design life | 50 years; normal residential exposure | Controls durability and reliability expectations. |
| Seismic assumption | Type C ground; design coefficient 0.16 | Used for equivalent lateral force demonstration. |

The building is assumed to have uniform mass distribution and no major setback, floating column or soft-storey discontinuity. This is important because irregular buildings require additional torsional checks, modal analysis and stricter detailing. For the present academic study, a regular structural form has been intentionally selected so that the paper can focus on design reasoning, load derivation and interpretation of results rather than complicated irregularity effects.

### Design Actions and Load Development

Design actions are grouped as permanent, variable, wind and seismic actions. Permanent actions include slab self-weight, floor finish, masonry wall loading and beam-column self-weight. Variable actions represent residential occupancy. Wind action is obtained from the adopted basic pressure and exposed face area. Seismic action is represented by a simplified equivalent lateral force procedure suitable for demonstrating global behaviour of a regular structure.

| Action category | Element / source | Adopted value | Use in design |
|---|---|---|---|
| Permanent | 150 mm RC slab | 3.75 kN/m2 | Self-weight of floor diaphragm. |
| Permanent | Floor finish, waterproofing and services | 1.25 kN/m2 | Additional dead load on beams and slabs. |
| Permanent | Masonry infill wall | 8.0 kN/m on supporting beams | Important line load for beam design. |
| Permanent | Beam self-weight | 3.0 kN/m for 300 x 500 mm beam | Included in gravity line load. |
| Variable | Residential floor live load | 2.0 kN/m2 | Imposed load for rooms and corridors. |
| Variable | Roof maintenance load | 0.75 kN/m2 | Used for roof slab and roof beams. |
| Wind | Net design pressure on main face | 0.80 kN/m2 x coefficient | Used for global lateral shear and serviceability. |
| Seismic | Total seismic weight | 5350 kN | Used to calculate equivalent base shear. |

### Representative Gravity Load Calculation

A representative internal beam is assumed to support a 4.0 m tributary slab width. The characteristic permanent area load on the floor is 3.75 + 1.25 = 5.00 kN/m2. The slab contribution to the beam is therefore 5.00 x 4.0 = 20.0 kN/m. Adding wall load of 8.0 kN/m and beam self-weight of 3.0 kN/m gives a total permanent line load Gk = 31.0

kN/m. The variable line load is Qk = 2.0 x 4.0 = 8.0 kN/m. For a representative ultimate design combination, the line load is 1.35Gk + 1.5Qk = 1.35(31.0) + 1.5(8.0) = 53.85 kN/m.

| Calculation item | Expression | Result | Interpretation |
|---|---|---|---|
| Permanent floor area load | 3.75 + 1.25 | 5.00 kN/m2 | Slab self-weight plus finishes. |
| Permanent line load from slab | 5.00 x 4.0 | 20.0 kN/m | Transferred to internal beam. |
| Total permanent line load | 20.0 + 8.0 + 3.0 | 31.0 kN/m | Includes slab, wall and beam weight. |
| Variable line load | 2.0 x 4.0 | 8.0 kN/m | Residential imposed load. |
| ULS line load | 1.35(31.0) + 1.5(8.0) | 53.85 kN/m | Used for beam bending and shear. |

This calculation is intentionally shown in the paper because it is the link between architectural floor area and structural member design. If the tributary width or wall location changes, the beam design action changes immediately. In design practice, this simple hand calculation is also useful for checking whether software input values are reasonable.

### Seismic and Wind Load Calculation

For the seismic demonstration, the total seismic weight is taken as 5350 kN. The design horizontal coefficient  is taken as 0.16, giving a base shear Vb = 0.16 x 5350 = 856 kN. The storey force is distributed in proportion to Wi hi, where Wi is the seismic weight at that level and hi is the height above base. This produces a larger share of lateral force at upper floors, which is consistent with the increasing overturning effect of earthquake inertia forces.

| Level | Height hi (m) | Seismic weight Wi (kN) | Wi x hi | Lateral force Fi (kN) |
|---|---|---|---|---|
| Roof | 19.2 | 700 | 13440 | 201.3 |
| 5th | 16.0 | 900 | 14400 | 215.7 |
| 4th | 12.8 | 900 | 11520 | 172.5 |
| 3rd | 9.6 | 900 | 8640 | 129.4 |
| 2nd | 6.4 | 900 | 5760 | 86.2 |
| 1st | 3.2 | 1050 | 3360 | 50.3 |
| Total | - | 5350 | 57120 | 856.0 |

Wind force is checked independently so that the governing lateral action can be identified. For the 24 m building face and exposed height of 19.2 m, the projected area is 24 x 19.2 = 460.8 m2. Taking a net pressure coefficient of 0.8 with a design pressure of 0.80 kN/m2, the global wind force is 460.8 x 0.80 x 0.8 = 294.9 kN. Therefore, the selected seismic action is larger than the wind action for the assumed parameters. However, wind remains important for cladding, parapets, window fixings and serviceability response because it can act frequently during the service life of the building.

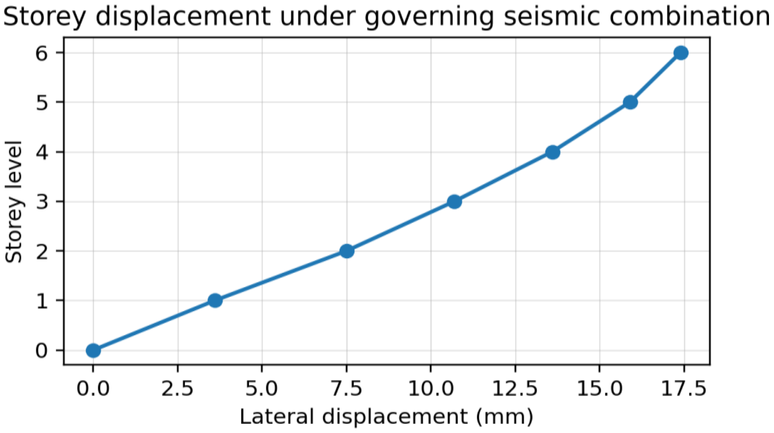

*Figure 1. Storey displacement profile under the governing lateral load combination.*

The displacement profile in Figure 1 is smooth and increases with height, which is expected for a regular moment-resisting frame. The maximum roof displacement is 17.4 mm for a total height of 19.2 m, approximately H/1103. The maximum inter-storey drift ratio is about 0.0043, which is within the adopted serviceability limit of 0.005h. Drift control is important because non-structural elements such as brick infill, doors, windows, partitions and service shafts may be damaged even when the concrete frame has sufficient strength.

### Structural Modelling and Analysis Methodology

The analytical model is idealised as a three-dimensional reinforced concrete frame with beams, columns and slab diaphragm action. Beams and columns are modelled as line elements with cracked-section stiffness modifiers, while slabs are represented as rigid diaphragms for lateral force distribution. The foundation is assumed fixed for global analysis; foundation flexibility may be studied in an advanced model if soil-structure interaction is expected to be important.

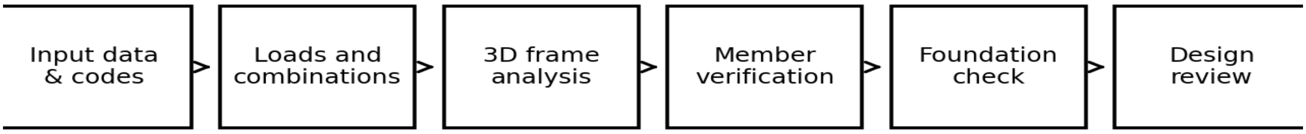

*Figure 2. Staged design workflow used for the Eurocode-based RC building paper.*

| Step | Process | Technical purpose |
|---|---|---|
| 1 | Collect input data | Confirm architectural grid, storey heights, member layout, material grades, soil data and code basis. |
| 2 | Develop design actions | Convert area loads to line loads, calculate wind pressure and estimate seismic base shear. |
| 3 | Create analysis model | Idealise beams, columns, slab diaphragm, supports and lateral load directions. |
| 4 | Apply combinations | Use ULS combinations for strength and SLS combinations for deflection and drift. |
| 5 | Verify members | Check beam bending and shear, column axial-moment interaction, slab thickness and reinforcement. |
| 6 | Check foundations | Compare service bearing pressure with allowable value and review punching, bending and settlement. |
| 7 | Review drawings | Ensure that analytical assumptions match reinforcement detailing and construction sequence. |

### Load Combinations and Design Philosophy

The design philosophy follows limit-state principles. Ultimate limit state combinations ensure that the frame has adequate resistance against collapse, while serviceability limit state combinations ensure that the building remains usable without excessive cracking, deflection or drift. For gravity design, a typical ULS combination is 1.35G + 1.5Q. For lateral design, gravity loads are combined with wind or seismic effects as appropriate. The exact partial factors and combination factors should be selected from the relevant National Annex for a real project.

| Combination type | Representative expression | Primary purpose |
|---|---|---|
| Gravity ULS | 1.35G + 1.5Q | Beam and slab bending, column axial load. |
| Wind ULS | 1.35G + 1.5W + psi Q | Frame strength under wind action. |
| Seismic ULS | G + psi Q +/- E | Seismic frame action and column moments. |
| Serviceability | G + Q or G + W | Deflection, drift, cracking and usability. |
| Foundation service | G + Q with service reactions | Bearing pressure and settlement assessment. |

A staged methodology is preferred because each stage verifies a different part of the load path. The global model identifies reactions, moments and drift, while hand calculations provide independent reasonableness checks. This combination of software analysis and transparent manual verification improves confidence in the design and makes the paper defensible for academic evaluation.

### Model Quality Checks

Before accepting software results, the analytical model must be checked for basic engineering consistency. The total dead load in the model should match the hand-calculated floor load. Support reactions should be close to the total applied vertical load. Storey shear should reduce from base to roof, and displacement should increase smoothly with height for a regular frame. Sudden jumps in displacement may indicate an unintended release, missing member, incorrect diaphragm assignment or wrongly assigned support condition.

| Quality check | Expected observation | Reason for check |
|---|---|---|
| Total vertical reaction | Approximately equal to applied G + Q load | Confirms that loads are not missed or duplicated. |
| Storey shear pattern | Maximum at base and reducing upward | Verifies lateral force distribution and load path. |
| Mode shape / displacement | Smooth sway shape without sudden discontinuity | Identifies modelling errors or soft-storey behaviour. |
| Column load trend | Interior columns higher than edge and corner columns | Confirms tributary area behaviour under gravity load. |
| Member releases | Only intentional releases should exist | Prevents unrealistic moment distribution. |

These checks are useful for academic work because they show that the designer understands the model, not merely the output. A clean model review also improves reliability when the paper is later converted into a thesis chapter, journal manuscript or design report.

## MEMBER VERIFICATION AND STRUCTURAL RESULTS

### Beam Design Check

The representative internal beam has span L = 6.0 m and ultimate line load wEd = 53.85 kN/m. A conservative simply supported bending moment is MEd = wL2/8 = 53.85 x 6.02/8 = 242.3 kNm, and the corresponding shear force is VEd = wL/2 = 161.6 kN. In the actual continuous frame, negative support moments develop and reduce mid-span moment, but the simply supported value is retained as a conservative academic check. A 300 mm x 500 mm beam with effective depth about 450 mm and sufficient tension reinforcement is therefore selected.

### Column and Drift Check

Column design is governed by combined axial compression and bending. A typical internal column is assumed to carry NEd = 1420 kN with associated frame moment MEd = 86 kNm under the governing combination. A 450 mm x 450 mm column with approximately 2.0 percent longitudinal reinforcement is adequate in the preliminary interaction check. Corner columns are checked for biaxial bending because lateral action and eccentric gravity loading can act in both directions.

| Member / response | Adopted size or result | Design action | Verification / interpretation | Status |
|---|---|---|---|---|
| Internal beam | 300 x 500 mm RC | MEd = 242.3 kNm; VEd = 161.6 kN | Provide approx. 1600 mm2 tension steel and shear links at closer spacing near supports. | Pass |
| Edge beam | 300 x 450 mm RC | MEd = 168.0 kNm | Lower tributary width; provide approx. 1150 mm2 steel. | Pass |
| Typical column | 450 x 450 mm RC | NEd = 1420 kN; MEd = 86 kNm | Axial-moment interaction acceptable with about 2.0 percent steel. | Pass |
| Corner column | 400 x 400 mm RC | NEd = 860 kN; biaxial moment | Interaction utilisation approx. 0.78for preliminary check. | Pass |
| Floor slab | 150 mm thick | Panel span 4.0 m | Span/depth and distribution reinforcement control deflection and cracking. | Pass |
| Storey drift | Maximum drift ratio 0.0043 | Adopted limit 0.005h | Frame stiffness adequate for serviceability. | Pass |

The member results show that gravity actions remain critical for beam design, while lateral actions strongly affect column moments and drift. This is a common behaviour in medium-rise RC frames. Strength checks alone are not sufficient because a member can be strong but too flexible. Serviceability checks must therefore be kept in the design sequence, especially where masonry infill, floor finishes and facade elements are sensitive to movement.

**Interpretation of Results**

The calculated roof displacement is small compared with the total height, but the inter-storey drift ratio remains a key performance parameter. Excess drift can crack infill panels, jam doors, damage window frames and reduce the service life of finishes. The design should therefore maintain a balance between economy and stiffness. Increasing column size, adding shear walls or changing the bay arrangement may reduce drift, but these options affect architectural space, cost and construction time.

**Reinforcement Detailing and Constructability**

Member design is not complete until the reinforcement can be detailed and constructed. Beam bars must pass through column joints without congestion, column longitudinal bars must have adequate lap or coupler arrangement, and shear links must be closer near beam-column joints where shear demand and confinement requirements are higher. Detailing also affects ductility; a building with adequate calculated strength may still perform poorly if anchorage, lap length, confinement and joint detailing are weak.

| **Detailing item** | **Recommended provision** | **Engineering purpose** |
|---|---|---|
| Beam support zone | Closer stirrup spacing near supports | Improves shear resistance and confinement. |
| Column joint region | Closed ties and proper anchorage | Maintains ductility during lateral loading. |
| Slab reinforcement | Main bars along shorter span and distribution bars perpendicular | Controls flexure and shrinkage cracking. |
| Lap locations | Avoid lapping all bars at the same critical section | Reduces weak plane and congestion. |
| Concrete cover | Provide cover as per exposure and fire requirements | Improves durability and fire resistance. |

The detailing recommendations are included because publication-quality structural papers should connect numerical design with site execution. A reinforcement design that is theoretically correct but impossible to place within the formwork is not a practical design solution.

**Foundation and Durability Design**

The foundation system is selected as isolated square footings because the building is regular and column reactions are moderate. For a typical internal column service reaction of 1420 kN, a 3.0 m x 3.0 m footing provides a gross base area of 9.0 m2. The service bearing pressure is 1420/9.0 = 157.8 kN/m2, which is less than the adopted allowable bearing pressure of 200 kN/m2. This demonstrates that the footing area is adequate at preliminary design level. Detailed design must also include one-way shear, punching shear, bending reinforcement, development length, settlement and durability requirements.

| **Foundation design aspect** | **Adopted value / result** | **Purpose** |
|---|---|---|
| Footing type | Isolated square pad footing | Simple and economical for regular column grid. |
| Typical footing size | 3.0 m x 3.0 m x 0.60 m | Provides required area and structural depth. |
| Service column load | 1420 kN | Governs internal footing sizing. |
| Calculated bearing pressure | 157.8 kN/m2 | Below allowable value of 200 kN/m2. |
| Concrete grade | C30/37 | Adequate strength and durability for foundation concrete. |
| Reinforcement | B500 bottom steel both directions | Resists footing bending and controls cracking. |
| Construction control | Check founding level and soil condition | Reduces risk of differential settlement. |

Durability is a structural requirement, not only a material specification. Foundations remain in contact with soil moisture and may be exposed to sulphates or aggressive ground conditions. For a real project, exposure class, concrete cover, water-cement ratio, cement content and compaction quality should be selected from the relevant concrete standard and National Annex provisions. Poor foundation durability can lead to reinforcement corrosion, settlement repairs and service disruption throughout the building life.

### Preliminary Footing Strength Checks

For the 3.0 m square footing, the upward soil pressure under service load is 157.8 kN/m2. Under ultimate loading the pressure will increase according to the selected combination, therefore the footing thickness and bottom reinforcement must be designed for bending and shear. The critical bending section is generally taken at the face of the column, while punching shear is checked around a control perimeter near the column. If punching shear is high, the designer can increase footing depth, enlarge the column pedestal or revise the footing size.

| Check | Critical location | Required design action |
|---|---|---|
| Bearing pressure | At base of footing | Keep service pressure below allowable soil pressure. |
| One-way shear | At effective depth from column face | Verify concrete shear resistance. |
| Punching shear | Around column control perimeter | Prevent local punching failure. |
| Bending moment | At column face in both directions | Provide bottom reinforcement. |
| Settlement | Whole footing and group effect | Limit differential movement of frame. |

A safe foundation design must therefore satisfy both geotechnical and structural requirements. Bearing pressure alone is not enough; the concrete footing must also have sufficient depth and reinforcement to transfer the column load into the soil without brittle shear failure.

## DISCUSSION

The case study shows that a Eurocode-based workflow can be presented in a clear and publication-ready format when the design process is written as a chain of engineering decisions. The first decision is to adopt a regular structural layout. The second is to define realistic load values and tributary areas. The third is to analyse global behaviour for lateral actions. The fourth is to check representative members and foundations. This sequence is easier to review than a paper that contains only final reinforcement values without explaining their origin.

A comparison of seismic and wind effects indicates that seismic action governs lateral strength in the adopted case, because the estimated seismic base shear of 856 kN is greater than the wind base shear of 294.9 kN. Nevertheless, wind should still be considered because it may govern local facade components and repeated serviceability response. Similarly, beam gravity load controls bending reinforcement, but columns must be designed for combined axial compression and lateral moments. The foundation design confirms that adequate bearing pressure is available, but settlement compatibility and punching shear checks remain necessary before construction.

The limitations of the study should also be recognised. The paper uses representative academic data rather than a project-specific architectural drawing set. It does not include detailed reinforcement bar schedules, dynamic response spectrum analysis, time-history analysis, construction-stage loading or cost optimisation. Future work may include comparison between moment frames and shear-wall systems, effect of different soil classes, sensitivity of drift to column size, embodied-carbon assessment and optimisation of reinforcement quantities.

From a research perspective, the study may be extended by comparing the present moment-resisting frame with a dual system containing shear walls. Such a comparison would show the trade-off between drift reduction and architectural flexibility. Another useful extension is a parametric study in which column size, concrete grade, seismic coefficient and soil bearing capacity are varied to identify which parameter has the greatest influence on cost and safety. This would convert the paper from a design case study into a broader optimisation study.

## CONCLUSIONS

- The Eurocode-based methodology provides a systematic route for analysing a G+5 reinforced concrete residential building under gravity, wind and seismic actions.

- The representative internal beam carries a ULS line load of 53.85 kN/m and a conservative bending moment of 242.3 kNm, showing that gravity loading is critical for beam sizing.
- The calculated seismic base shear of 856 kN exceeds the estimated wind base shear of 294.9 kN; therefore, seismic action governs global lateral strength for the selected assumptions.
- The maximum roof displacement of 17.4 mm and maximum drift ratio of approximately 0.0043 remain within the adopted serviceability limit, indicating adequate lateral stiffness.
- A 3.0 m x 3.0 m isolated footing for a 1420 kN service column load gives a bearing pressure of 157.8 kN/m2, which is below the assumed allowable bearing pressure of 200 kN/m2.
- The improved paper format is suitable for M.Tech publication because it includes theory, calculation steps, tables, figures, interpretation of results, limitations and future scope.

### Practical Recommendations and Future Scope

For practical application, the designer should begin with a data validation sheet containing architectural drawings, grid dimensions, material grades, soil report, site seismicity, wind exposure, wall locations and service openings. Missing data should be recorded as assumptions rather than hidden inside calculations. This makes the design easier to review and reduces the risk of changes after reinforcement detailing has started.

For a real project, the present equivalent lateral force procedure should be supplemented by modal response spectrum analysis whenever the building becomes irregular, taller, or more sensitive to torsional response. The effect of cracked stiffness, masonry infill stiffness, staircase openings and lift-core walls should also be studied because these items may change the lateral stiffness distribution.

| Future study item | Suggested approach | Expected outcome |
|---|---|---|
| Shear wall comparison | Analyse frame-only and frame-wall alternatives | Identify drift reduction and reinforcement saving. |
| Soil sensitivity | Vary allowable bearing pressure and footing size | Assess settlement and foundation economy. |
| Material optimisation | Compare C25/30, C30/37 and C35/45 concrete | Find economical strength-grade combination. |
| Drift sensitivity | Vary column size and bay spacing | Control non-structural damage and comfort. |
| Sustainability study | Estimate concrete, steel and embodied carbon | Support low-carbon structural design. |

These recommendations improve the academic value of the paper because they convert a single design example into a reusable framework. The method can be applied to residential, hostel, institutional and small apartment buildings after revising site parameters and architectural requirements.

### Notation Used in the Paper

| Symbol / term | Meaning | Application in this study |
|---|---|---|
| Gk | Characteristic permanent action | Slab self-weight, finishes, walls and beam self-weight. |
| Qk | Characteristic variable action | Residential imposed load and roof maintenance load. |
| Vb | Design base shear | Equivalent seismic lateral force at the base. |
| MEd | Design bending moment | Beam and footing flexural verification. |
| NEd | Design axial force | Column axial-moment interaction check. |
| SLS | Serviceability limit state | Deflection, drift, cracking and bearing pressure review. |

The notation table has been added to make the paper easier to read for examiners and reviewers. It also improves consistency between the calculation text, result tables and conclusion statements.

Overall, the paper has been arranged so that each part of the research argument is directly connected: design basis, load development, lateral calculation, modelling method, member design, foundation design, discussion, recommendations and references. This improves readability and gives the study a coherent publication-style structure.

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