

Study on Planning, Analysis and Design of a Multistoried Hotel Building

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Abstract - Multi-storied buildings are increasingly common due to rising land costs and space scarcity in urban areas. This paper presents the planning, analysis and design of an earthquake-resistant, 16-storied, 5-star hotel building located in seismic zone III. Functional planning was carried out to satisfy the requirements of the National Building Code 2005, applicable state building rules, and hotel-rating criteria specified by the Ministry of Tourism, Government of India. Structural modeling, analysis and design were performed using SAP2000 based on the limit state method of IS 456:2000, with loads estimated as per IS 875 (Parts I-III) and seismic forces computed by the equivalent static method of IS 1893 (Part I). Design results obtained from the software for representative beams, columns, slabs and staircases were validated through independent manual calculations, and ductile detailing was carried out as per IS 13920:1993. The manual and software-based results were found to be in close agreement, confirming the reliability of the software-based design.

Key Words: *Multistoried building, earthquake-resistant design, reinforced concrete, SAP2000, hotel planning, limit state method.*

1. INTRODUCTION

Present-day buildings are constructed with new methods and materials driven by growing population, land scarcity and rising land costs, which have pushed cities toward vertical development. A hotel is an establishment providing short-term lodging and boarding; modern hotels additionally provide amenities such as en-suite bathrooms, climate control, business and fitness centers, and function facilities. Hotel quality is generally classified using star-rating systems, with India following a similar scheme under the Ministry of Tourism.

This work deals with the planning, analysis and design of an earthquake-resistant, 16-storied, 5-star hotel situated in seismic zone III as per IS 1893 (Part I). All facilities and requirements of the hotel are provided in accordance with the National Building Code (NBC) 2005 and applicable state building rules, with due consideration to earthquake-resistant construction concepts and Ministry of Tourism rating criteria. Plan drawings were prepared using AutoCAD, and the plan was subsequently refined for economy, with furniture arrangement and interior planning finalized. Structural

modeling, analysis and design were carried out using SAP2000, and results were validated through manual calculations.

1.1 Objectives

- Functional planning of an earthquake-resistant, 16-storied, 5-star hotel.
- Familiarization with standard software packages such as AutoCAD and SAP2000.
- Preparation of drawings, analysis and design using standard software packages.
- Manual design of structural components and validation of software results.

2. METHODOLOGY

The step-by-step design procedure adopted is summarized below:

- Collection of site data, including the site plan and bore-hole details.
- Preparation of a functional plan satisfying NBC 2005, state building rules and Department of Tourism hotel-rating requirements.
- Three-dimensional structural modeling of the building in SAP2000.
- Estimation of dead, live and wind loads as per IS 875 (Parts I, II & III).
- Computation of seismic loads by the equivalent static method as per IS 1893 (Part I).
- Analysis of the 3-D frame for all governing load combinations, followed by limit-state design (IS 456:2000) of slabs, beams, columns and the pile foundation.
- Grouping of members with marginal variation in reinforcement, followed by ductile detailing as per IS 13920:1993.
- Independent manual design of representative members to validate software output.

2.1 Structural Analysis and Design Methods

Manual methods of analysis for indeterminate frames include the slope-deflection method, moment-distribution method, Kani's method and matrix (stiffness/flexibility) methods, along with approximate methods such as the portal and cantilever methods for lateral loads. For the present, highly indeterminate 16-

storied frame, computer-based matrix analysis was adopted using SAP2000 v15.0, an integrated finite-element package that couples 3-D structural modeling, analysis and design (steel, concrete, aluminum and cold-formed sections) within a single interface.

Of the three common design philosophies for reinforced concrete - working stress, ultimate load and limit state methods - the limit state method (IS 456:2000) was adopted, as it accounts for both strength and serviceability requirements using partial safety factors of 1.5 for concrete and 1.15 for steel. Vertical loads are transferred from slabs to beams, from beams to columns, and finally from columns to the pile foundation; the design sequence therefore followed estimation of loads, preliminary sizing, and analysis/design of slabs, beams, columns and the foundation, in that order.

3. STRUCTURAL MODELING AND ANALYSIS

The building was idealized as a 3-D moment-resisting frame in SAP2000 (v15.0, concrete code IS 456:2000). Roof and floor slabs were modeled as two-way restrained shell elements, and the frame was analyzed for 22 load combinations comprising dead, live, wind (IS 875 Part 2) and seismic (IS 1893) cases with appropriate partial safety factors. Table 1 summarizes the principal material and section properties used in the model.

Table 1: Material and Section Properties Used in the SAP2000 Model

Element	Grade / Section	Size (m)
Concrete	M30 ($f_{ck} = 30$ MPa)	-
Reinforcement	Fe500 ($f_y = 500$ MPa)	-
Main beam	Rectangular	0.45 x 0.30
Column C1 (typical)	Rectangular	1.20 x 0.40
Floor / roof slab	Shell (plate-thin)	0.15 thick

Deformed shapes, shear force diagrams (SFD) and bending moment diagrams (BMD) were generated for all governing combinations, and joint forces/moments were tabulated for each frame member. By examining the analysis output, members with marginal variation in required reinforcement were grouped together and assigned a common reinforcement pattern, which reduced the number of distinct reinforcement details while remaining conservative for all members in a group.

4. RESULTS AND DISCUSSION

The reinforcement obtained from the SAP2000 output for critical beam, column, slab and staircase sections was cross-checked using manual calculations

based on IS 456:2000 and SP:16. A representative beam (Beam 295, 300 mm x 450 mm) and column (Column 117, 400 mm x 1200 mm) were selected for detailed manual verification; the results are compared in Table 2.

Table 2: Comparison of Software and Manual Design Results

Member	Reinforcement (SAP2000)	Reinforcement (Manual)
Beam 295 - Bottom	4 - 25 mm dia	4 - 25 mm dia
Beam 295 - Top	3 - 20 mm dia	3 - 20 mm dia
Column 117 - Longitudinal	16 - 32 mm dia	16 - 32 mm dia

For Beam 295, the SAP2000 output at the critical section gave a factored design moment of 254.8 kN-m, exceeding the limiting moment of resistance of the singly reinforced section (167 kN-m); a doubly reinforced section was therefore adopted, giving a tension steel requirement of about 1962 mm² (4 bars of 25 mm dia) and compression steel of about 754 mm² (3 bars of 20 mm dia), matching the software output. Shear design at the critical section ($V_u = 165.2$ kN) required 8 mm dia, 2-legged stirrups at 200 mm c/c near supports, increasing to 300 mm c/c towards mid-span.

For the ground-floor column (Column 117, subjected to an axial load of about 9002 kN with biaxial moments), the interaction-ratio check per SP:16 gave $M_{ux}/M_{ux1} + M_{uy}/M_{uy1} = 0.083$, well within the limiting value of 1.0 for the reinforcement percentage assumed ($p = 2.7\%$), confirming adequacy of the 16 bars of 32 mm dia obtained from the software. The manual and software-based reinforcement quantities for both members matched closely, as illustrated in Fig. 1, confirming the reliability of the SAP2000-based design for the remaining grouped members.

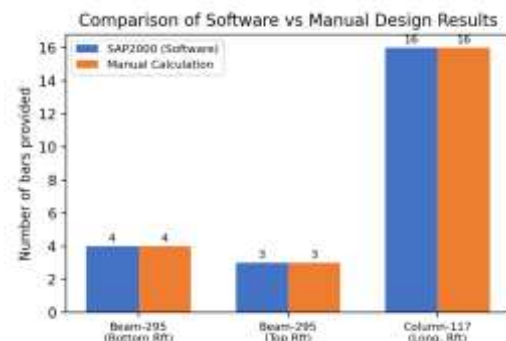


Fig -1: Comparison of Software and Manual Reinforcement Quantities

Similar validation was carried out for the two-way restrained slab panels and the dog-legged staircase, both designed manually using IS 456:2000 and SP:16, since these elements are not directly designed by SAP2000.

The pile foundation was designed for the maximum column reactions obtained from the software, with pile capacity determined from an assumed sub-surface soil report and the pile cap designed as a rigid cap in bending and one-way/two-way shear.

5. CONCLUSION

The planning, analysis and design of a 16-storied, earthquake-resistant, 5-star hotel building have been carried out successfully. Functional and structural planning satisfied NBC 2005 and hotel-rating requirements, and drawings were prepared using AutoCAD. Structural analysis and design were performed using SAP2000 and independently verified by manual calculation for representative beams, columns, slabs, staircases and the pile foundation; the manual and software results were found to be in close agreement. Ductile detailing of all members was carried out as per IS 13920:1993 to improve seismic performance. It is noted that, while the design substantially improves earthquake resistance, no structure can be rendered completely immune to earthquake effects.

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