Comparative Seismic Analysis and Design of RCC and Composite Structure for Different Seismic Zones and Soil Conditions - Review

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Abstract: The demand for the construction of multi-story buildings is increasing rapidly due to growingcompetition and the need for more economical and spacious buildings. Theoretical calculations forsuch structures are critical and there is a growing demand for fast software to speed up the process. This dissertation uses computer program such as ETABS to design and analyze a multi-story building in two forms i.e. R.C.C and Composite Structure. The Indian design code is used for the design and the structure analyzed is an R.C.C and Composite Structure with 10 story and 15 stores.

The seismic performance of structures is a critical factor in designing and constructing buildings in seismic-prone regions. This dissertation presents a comparative study of the seismic resistance of Composite and Reinforced Concrete (RCC) structures under different soil conditions (Rock or Hard soil, Medium soil, Soft soil) and seismic zones (II-Nagpur, III-Pune, IV-Delhi, V-Srinagar) using the ETABS software. The project evaluates the performance of composite and RCC structures in terms of lateral deflection, story drift, and base shear values and compares their response using the Response Spectrum Method and Time History Method. The study investigates the effects of different seismic zones (II-Nagpur, III-Pune, IV-Delhi, and V-Srinagar) and soil conditions (Rock or Hard soil, Medium soil, Soft soil) on the seismic resistance of these structures. The design of the structure follows the Indian design code, which includes the following codes: IS 456:2000, IS Code 800, IS Code 1893:1984, and IS Code 11384:1985 and so on.

Composite structures are found to be the best mode of construction for high-rise building while comparing with the conventional R.C.C structures as they serve well for various parameters like lateral deflection, story drift and base shear values. The findings of this study can assist in selecting the most efficient and reliable type of structure for seismic resistance in different seismic zones and soil conditions.

Keywords: Indian Design Code, RCC Structure, Composite, Seismic Resistance, Soil Conditions, Seismic Zones, Response Spectrum Method etc.

I. INTRODUCTION

In the past, buildings were typically designed with either concrete or masonry structures. However, due to the failure of these structures during earthquakes, structural engineers have been exploring alternative methods of construction. Composite steel-concrete systems have been identified as a promising solution with benefits such as highly economical structural systems, fast construction, excellent durability, and superior seismic performance if properly configured. Despite these advantages, many engineers in India remain hesitant to adopt this method due to their unfamiliarity with it, lack of awareness, and the perceived complexity of its analysis and design.

It is worth noting that while composite construction may not be as popular as other methods, it has the potential to be highly beneficial for medium and high-rise structures. By combining the advantages of both steel and concrete, steel-concrete composite structures can be built that are both efficient and economic. Therefore, it may be advantageous to consider the use of steel-concrete composite structures instead of traditional reinforced concrete structures.

Seismic loads pose a significant threat to the safety and stability of buildings and structures, particularly in seismic-prone regions. The resistance of structures to seismic loads depends on various factors such as soil conditions, structural design, material properties, and seismic zones. The choice of structural system is also critical in ensuring the seismic resistance of buildings. Reinforced concrete (RCC) and composite structures are two commonly used structural systems for seismic-resistant building design. However, the selection of the most efficient and reliable structural system for seismic resistance in different seismic zones and soil conditions is still a challenging task for design engineers and architects.

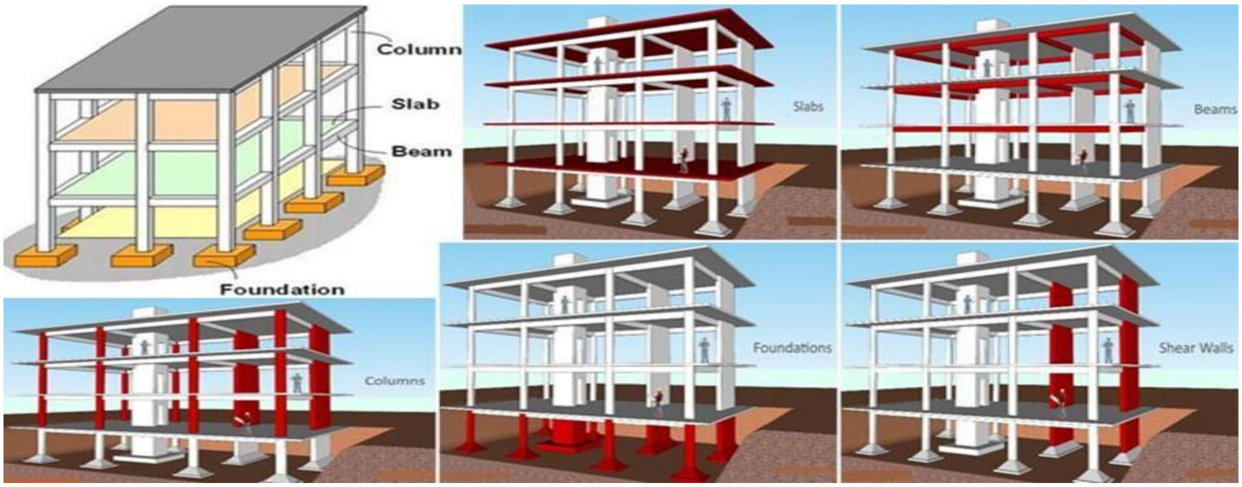


Fig. 1 Element of RCC Structure

II. RESEARCH OBJECTIVE

The objectives of the project "Seismic Resistance of Composite and RCC Structures in Different Seismic Zones and Soil Conditions: An ETABS-based Comparison Study" are:

1. To study design software like as ETABS.
2. To investigate the seismic resistance of composite and RCC structures under different soil conditions and seismic zones.
3. To compare the performance of composite and RCC structures in terms of lateral deflection, story drift, and base shear Results.
4. To analyses the effect of seismic zones and soil conditions on the seismic resistance of composite and RCC structures.
5. To evaluate the efficiency of composite and RCC structures in resisting seismicloads using the response spectrum method and time history method.
6. To suggest recommendations for the selection of the most efficient and reliable type of structure for seismic resistance in different seismic zones and soil conditions.

III. LITERATURE REVIEW

Ima muljati. et.al [1] They studied the performance of displacement based design and force based design on concrete frame. They concluded that displacement based design was superior in predicting the seismic demand (story drift) than force based design. The Displacement Based Design (DBD) designs structure for a particular performance while the Force Based Design (FBD) did several iterations to justify the codal provisions.

Varsha patil. et.al [2] Steel structures, in fact, exhibited elastic behavior up to relatively high and usually well-define stress level by quite easy to connect beam members in a short time. Due to Service requirement in the market, it was necessary to reduce the construction time and cost by adopting simple and effective construction methodologies. The two main benefits of fast construction were a reduction in investment in the form of interest and early return of capital invested. The most efficient utilization of steel concrete composite construction led to more usable space and joint displacement at top was less due to higher stiffness in members compared to RCC steel structures.

Pallavi Harish Wagh. et.al [3] They studied steel was a universal construction material in many multi-story commercial buildings and factories as well as in bridges. Both steel and concrete resulted in quick construction and good bonding properties. The two different materials were completely compatible and complementary to each other. Steel concrete composite construction was the single unit under loading and they have almost same thermal expansion. This method was more economic than complete steel and reinforced concrete structures. The weight of steel and concrete structure was reduced as comparedto RCC structure due to small structural steel section, resulting in minimizing the foundation cost. Comparison of story drift for RCC and composite structures varied from 22% to 32%. Due to an increase in axial load in RCC structures, they had higher values in bending moment and shear force.

Samadhan Jagadale. et.al [4] In this study, the composite structures are the latest concepts for high rise buildings and resulted in rapid construction. Steel frame obtained a good response compared to RCC, but the composite frame was suitable for high rise buildings. From the results, the lateral displacement of top story of composite frame was 15% more than RCC frame and 17% less than steel frame. In G+7 story beam, the maximum shear force in composite frame was nearly 40.45% greater than RCC frame and 112.29% less than steel frame and the maximum bending moment for composite frame was 23.42% greater than RCC frame and 178.83% less than steel frame. The axial load on footing was higher for RCC frame than composite frame and steel frame, which was equal to 24% and 81%, respectively. Finally cost for G+7 story building for composite frame was nearly half than the steel frame and 15% higher than the RCC frame.

Madhav Rana. [5] In this study, steel structure gave better resistance against lateral and various other load combinations. Steel was a recyclable material and depending upon the property requirement, it can be used. The bracing systems were well known to increase the stiffness of any type of building usually it was provided at the corners to resist against loading. Maximum displacement at corner columns for 'an arc' type brazing 'Av arc' type bracing, single elliptical and double elliptical bracing was carried out. 'Av arc' bracing had the least maximum displacement and it was the most effective bracing system. The final result for material quantity of steel was less in 'An Arc' type bracing and more at double elliptical bracing system.

Anargha. B. S [6] the paper was an attempt to study the behavior of reinforced concrete, steel and composite structures under the effect of seismic loading. The parameters considered were base shear, displacement and story drift.

Krunal P. Suthar. et.al [7] the comparative study was conducted on seismic analysis of (G+10) R.C.C, steel and steel concrete composite building. The aim of the study was to compare the seismic performance of a 3D (G+10)story RCC, steel and Composite building frame situated in earthquake zone IV. All frames were designed for same gravity loadings, with RCC slabs used in all three types of buildings. The sections of beam and column were made of either RCC, Steel or Steel-concrete composite sections. Equivalent static method and Response Spectrum method were used for seismic analysis with ETABS 2017 software used to compare the results based on fundamental time period, displacements, story drift, base shear, story weight and story stiffness. The Comparative study based on seismic analysis concluded that RCC construction was best suited for low rise buildings among all the three types of constructions. However, in a High rise building construction, Composite was a better option than RCC and Steel Structures.

IV. METHODOLOGY

i) Response Spectrum Method

A response spectrum is simply a plot or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency that are forced into motion by same base vibration. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of building to earthquake. The science of strong ground motion may use some values from the ground response spectrum for correlation with seismic damage.

In technical terms it can be said that it is the representation of the maximum response of idealized single degree of freedom having certain period and damping during earthquake ground motion. The maximum response is plotted against the undammed natural period and for various damping values can be expressed in terms of maximum relative velocity or maximum relative displacement. The characteristics of seismic ground vibrations expected at any location depends upon the magnitude of earthquake, its depth of focus, distance from the epicenter, characteristics of the path through which the seismic waves travel, and soil strata on which the structure stands. The random earthquake ground motions, which cause the structure to vibrate, can be resolved in any three mutually perpendicular directions.

Limitations of Study

1. Due to the more dead weight of RCC, it is less used in high-rise buildings, as more loads will be there on the foundation.
2. At end of life, concrete can be crushed and recycled but the recycled material cannot be used for new building concrete.
3. For multi-storied building the RCC column section for is larger than steel section as the compressive strength is lower in the case

Seismic Base Shear

According to IS 1893 (Part-I): 2016, Clause 7.5.3 the total design lateral force or design seismic base shear (V_b) along any principal direction is determined by

$$V_b=Ah*W$$

Where,

Ah is the design horizontal acceleration spectrum

W is the seismic weight of building

Design Horizontal Acceleration Spectrum Value

For the purpose of determining the design seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I and II are merged into Zone II in fifth revision of code. According to IS 1893: 2016 (Part 1), Clause6.4.2 Design Horizontal Seismic Forces coefficient Ah for a structure shall be determined by following expression.

$$Ah = (Z/2)*(I/R)*(SA/G)$$

Where,

Z = Zone Factor Seismic Intensity

ii) Time History Method

Time history analysis techniques involve the stepwise solution in the time domain of the multi-degree-of-freedom equations of motion which represent the actual response of a building. It is the most sophisticated analysis method available to a structural engineer. Its solution is a direct function of the earthquake ground motion selected as an input parameter foe a specific building. This analysis technique is usually limited to checking the suitability of assumptions made during the design of important structures rather than a method of assigning lateral forces themselves.

V. PROBLEM FORMULATION

The implications of the seismic resistance study of composite and RCC structures in different seismic zones and soil conditions are as follows:

1. The study provides guidance to structural engineers and designers for selecting the appropriate structural system for seismic-resistant design. The results indicate that composite structures are a more viable option for seismic-resistant design as compared to RCC structures.
2. The study highlights the importance of soil conditions in seismic-resistant design. The study recommends that soil conditions must be taken into account when designing structures for seismic resistance, and site-specific seismic hazard analysis should be carried out.
3. The study emphasizes the importance of special detailing and reinforcement techniques for enhancing the seismic performance of structures. The detailing and reinforcement techniques used in this study were effective in enhancing the seismic performance of both composite and RCC structures.
4. The study provides insights into the cost-effectiveness of composite structures as compared to RCC structures. The results indicate that composite structures can be more economical than RCC structures, which can be a significant factor in large-scale construction projects.
5. The study highlights the need for further research on seismic-resistant design and the importance of incorporating new materials and construction techniques to improve the seismic performance of structures.
6. Overall, the study's implications can help improve seismic-resistant design practices and contribute to the development of more robust and resilient structures in earthquake-prone regions.

Table No: 1 Details Features of Building

Type of structure	Frame structure RCC and Composite Structure
Moment-Resisting frame	SMRF
No. of Stories	G+10, G+15
Height of each story	3m
Height of ground story	2.00m
Thickness of slab	150mm
Thickness of outer wall	150mm
Thickness of inner wall	150mm

Grade of reinforcing steel	Fe 415 & Fe 500
Density of concrete	25 kN/m3
Density of wall	20 kN/m3
Grade of concrete in slab	M30
Grade of concrete in beam	M30
Grade of concrete in column	M40
Grade of concrete in footing	M30
Seismic Analysis	Dynamic (Response Spectrum and Time History)
Seismic zone	I, II, III, IV And V
IS Code	IS 456 2015, IS 875-2015 part –I, II & III. IS 1893-2016, IS 13920 2016
Basic wind speed	39m/sec

Load Case and Load Combination

Unless otherwise specified, all loads listed, shall be considered in design for the Indian Code following load combinations shall be considered,

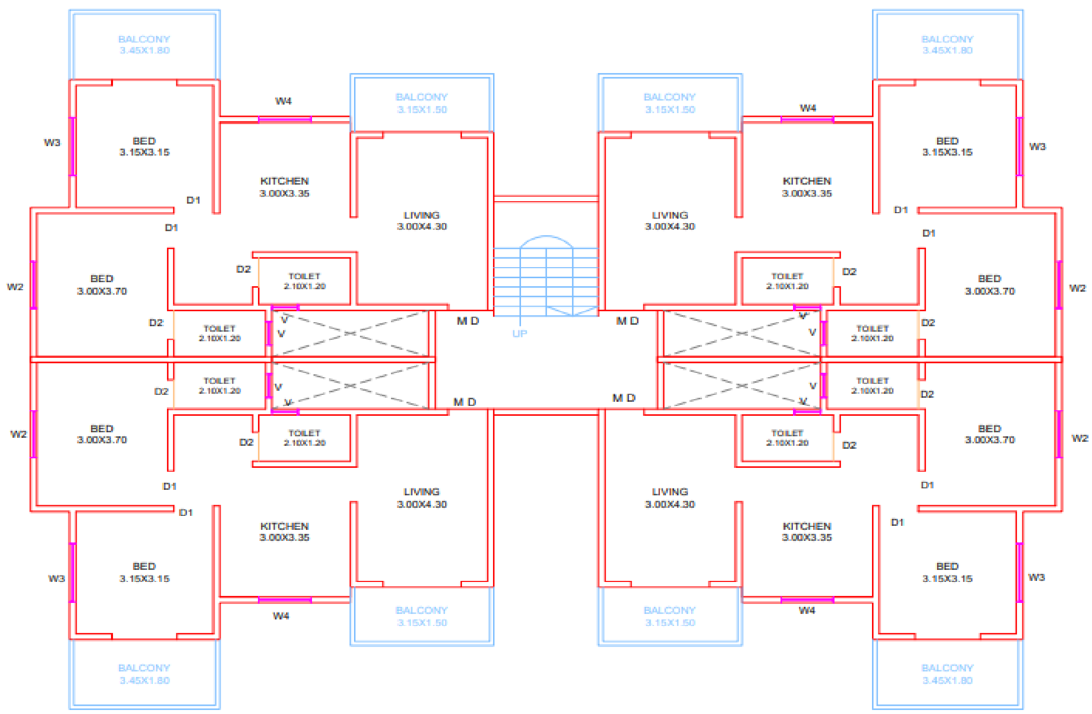
Load Case

1) DL: Dead load
2) LL: Live load
3) EQ: Earthquake load
4) W: Wind Load

Load Combination

1) 1.5DL+1.5LL
2) 1.2DL+1.2LL + 1.2EX
3) 1.2DL+1.2LL- 1.2EX
4) 1.2DL+1.2LL+1.2EY
5) 1.2DL+1.2LL - 1.2EY
6) 1.2DL+1.2LL+1.2WLX
7) 1.2DL+1.2LL-1.2WLX
8) 1.2DL+1.2LL+1.2WLY
9) 1.2DL+1.2LL-1.2WL

A. Building Plan



Conclusions

The response of reinforced concrete building And composite building have been evaluated in order to study the effect of it on seismic demand of the building by introducing this in different seismic zone with various soil in G+10 story building. The effects of different types of structure i.e. RCC & composite structure on elastic seismic demands are evaluated by Response Spectrum Analysis and Time History Analysis Method.

Relative Analysis in different types of structure i.e. RCC structure and Composite structure. The structures are analyses for earthquake zone II, III, IV and V with medium soil and Results Compare. It has been made on different structural parameters viz. base shear, Earthquake displacement, wind displacement and story drift etc. Grounded on the analysis results following conclusions are drawn.

VI. FUTURE SCOPE

The need for a dissertation on "Comparative Seismic Analysis and Design of RCC and Composite Structure for Different Seismic Zones and Soil Conditions"

1. To investigate the behavior of reinforced concrete (RCC) and composite structures under seismic loads and to determine which type of structure performs better under different seismic zones and soil conditions.
2. The seismic behavior of a structure depends on its design and the characteristics of the ground motion it experiences. Thus, it is important to compare the performance of RCC and composite structures to determine whichtype of structure is more suitable for a given seismic zone and soil condition.
3. Additionally, the comparative analysis can help engineers and designers make informed decisions regarding the selection of building materials and construction techniques, which can significantly affect the safety of a structure.
4. Furthermore, the results of the comparative analysis can be used to develop guidelines and recommendations for the design of RCC and composite structures in different seismic zones and soil conditions, which can help improve the safety and resilience of buildings in earthquake-prone areas.
5. Overall, the dissertation on "Comparative Seismic Analysis and Design of RCC and Composite Structure for Different Seismic Zones and Soil Conditions" is crucial to improving the understanding of the behavior of different types of structures under seismic loads and to develop guidelines for the design of safe buildings in earthquake-prone regions.

REFERENCE

[1] Ima Muljati, Fransiscus Asisi and Kevin Willyanto. "Performance of force based design versus direct displacement based design in predicting seismic demands of regular concrete special moment resisting frames." Procedia Engineering 125(2015) 1050-1056.

[2] Varsha Patil, K.S. (August 2015). “Comparative Study on Dynamic Analysis of Composite, RCC & Steel Structure”. International Journal of Engineering Technology, Management and Applied Sciences, 8.

[3] Pallavi Harish Wagh, Vishwajeet Kadlag (2019). “Comparative study on analysis and design of RCC and composite structure”. ISSN: 2454-132X. (Volume 5, Issue3).

[4] Samadhan Jagadale, M.R. Shiyekar, Y.M. Ghugal. (2019). “Comparative Study of Steel, RCC and Composite Frame Building”. Volume: 06 Issue: 07.

[5] Madhav Rana (2019). “Dynamic Analysis of Steel Frame Structure (Regular in Plan) using Curved Bracing System”.

[6] Anargha B.S (2019). “Comparative Study on Behaviors of R.C.C and Composite Multi-storeyed Building Using ETABS”. ISSN 0973-4562 Volume 14, Number 12, 2019.

[7] Krunal P. Suthar, Arjun M. Butala (2020). “Comparative Study on Seismic Analysis of (G+10) R.C.C, Steel and Steel-Concrete Composite Building”. Volume: 07 Issue: 05.

[8] Bhanu Prakash P.M, Dr. Vijaya Kumar Y.M, T.A. Srirama Rao (2021). “Review on Comparative Study on RCC and Steel Structure for Different Criteria`s”.Volume: 10 Issue: 4(2) ISSN: 2277-7881.

[9] Ankit Kumar (2021). “A Review Paper on Comparative Study on R.C.C and Composite Structure for Seismic Analysis Using Response Spectrum Method”. Volume: 03/Issue: 09.

[10] A. Sattainathan Sharma, R. Anjughap Priya, R. Thirugnanam and P. Rathna Priya (2016) “Comparative Study on Multi-storey Structure of R.C.C and Composite Material”. Vol 9(2).

[11] Prof. S. S. Charantimath, Prof. Swapnil B. Cholekar, Manjunath M. Birje. “Comparative Study on Structural Parameter of R.C.C and Composite Building”, Civil and Environmental Research, Vol.6, Issue.6, 2014, pp.2224-5790.

[12] J. Chiranjeevi Yadav, L. Ramaprasad Reddy. (2017) “Dynamic Analysis of G + 20 Residential Building in Zone2 and Zone5 by Using ETABS”. Volume VIII /Issue 3 / APR 2017.

[13] Shweta A. Wagh, Dr. U. P. Waghe,

"Comparative Study of R.C.C and Steel Concrete Composite Structures", International Journal of Engineering Research and Applications, Vol. 4, Issue 4 (Version 1), April 2014, pp.369-376.
[14] D.R. Panchal and P.M. Marathe, "Comparative Study of RCC, Steel and Composite (G+30 Storey) Building", Institute of Technology, Nirma University, Ahmedabad – 08-10 December, 2011, pp382-481.
[15] Rutvik Naik, Aniket Patil, Nikhil Shirude, Rohitkumar Ranguwar, "Comparison between RCC and Steel Structure Using Software". IRJET, Volume: 08, Issue: 06,June 2021.
[16] IS: 456(2000) ― Indian Standard Code of Practice for Plan and Reinforcement concrete (Fourth Revisions), Bureau of Indian Standards (BIS), New Delhi.
[17] IS 1893-1 (2002): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings.
[18] IS: 13920-1993 ― Ductile Detailing of Reinforced of Concrete StructureSubjected to Seismic Forces Code of Practice.
[19] IS 800(1984), IS 800(2007), ― Indian Standards Code of Practice for General Construction in Steel, Bureau of Indian Standards (BIS), New Delhi.
[20] IS 875(1987-Part 1), ― Code of Practice for Design Loads (other than Earthquake) For Buildings and Structures, Dead loads, Bureau of Indian standards(BIS), New Delhi.
[21] IS 875(1987-Part2), ― Code of Practice for Live Loads, Bureau of IndianStandards (BIS), New Delhi.
[22] IS 875(1987-Part3), ― Code of Practice for Wind Loads, Bureau of IndianStandards (BIS), New Delhi.
[23] IS11384 (1985), ―Code of Practice for Design of Composite Structure, Bureau of Indian Standards (BIS), New Delhi.