A Review on Mono Column Multi-Storey Structural System Using Composite Material

*Ankur Pandey[1], Vaibhav Singh[2] and Gaurav Awasthi[3]
[1]M.Tech student, Dept. Of Civil Engineering, SVVV Indore, M.P
[2]Assistant Professor, Dept. Of Civil Engineering, SVVV Indore, M.P
[3]Assistant Professor, Dept. Of Civil Engineering, SVVV Indore, M.P
*apcivil.08@gmail.com

Abstract

The rapid increase in population and scarcity of land tends to the development of construction technology and high rise structures. The supporting condition of structural members determines their stability during their lifetime. A structure is said to be stable when it satisfies all stability requirements. Structures will be more stable when all the sides proportionally to balance the static and dynamic loads support it; the structure has supposed to be supported. Satisfying the requirement of stability conditions for a single column structures will be a complicated one, compare with the structures supporting in all the sides depends upon their configuration. For single column & floor response of structure under linear & dynamic loading, results are studied for deflection, bending moment; shear force, torsion and storey displacements.

Keywords: Mono column structure, Static and Dynamic loading, multi storey building, E-Tabs, Composite Material.

1. Introduction

Structure supported on a mono column provides large serviceable floor space compared to structure supported on many columns. They save ground space as requires less area for providing foundation and provides more space for parking. Maximum space utilization is considered will serve its maximum serviceability.An extensive literature review is carried out on the single column supported floor in multi- storey building by using composite material. Majority of previous works over steel concrete composite material in structure. A very few literature work is available over the analysis & design a structure supported on single Column Basically, in all research works different types of a structure supported on mono column by using material i.e.: RCC OR steel are taken for supporting whole structural block but each floor in multi-storey structure independently supported on single column using composite material is not carried out in any research work Literature review is divided into four sections.

2. Literature Review

For this study literature review is categorized in to four sections namely structure with mono column, structural shape, multi storey structure and material

2.1. Structural Shape

2.1.1. Anupam Rajmani et. al. (2015): studied a tall building, whose shape is unsuitable, often requires a great deal of steel or a special damping mechanism to reduce its dynamic displacement within the limits of the criterion level for the design wind speed. Understandably, an appropriate choice of building shape and architectural modifications are also extremely important and effective design approaches to reduce wind and earthquake induced motion by altering the flow pattern around the building, hence for this research work four different shaped buildings are generally studied namely circular, rectangular, square and triangular. To achieve these purposes, firstly, a literature survey, which includes the definition, design parameters, and lateral load considerations of tall buildings, is presented. Then the results are interpreted for different shaped buildings and of different stories thereby concluding as to which shaped high rise building is most stable for different conditions. Researchers conclude that, For 15 storied building the most stable structure is circular shape and triangular shape for maximum earthquake and maximum wind load respectively, similarly for 30 storied building, rectangular shape is most stable for maximum earthquake and wind load and for 45 storied building circular shape & rectangular shape is most stable for maximum earthquake and wind load respectively.

2.1.2. Hani Buri et. al. (2008): reveal the potential in the domain of folded plate structures. An interdisciplinary team investigates architectural, structural and mathematical aspects of folded plate structures built from cross laminated timber panels. The main concern of the architectural part is the form finding process which is inspired by Origami, the Japanese art of paper folding. Based on a simple technique, Origami gives birth to an astonishing formal richness and variability. Complex geometries are generated in an economic way. Researchers proposed new methods to generate rapidly complex folded plate structures that can be built with cross laminated timber panels. Composition and dimensions of these panels as well as the possibility to mill them by Computer Numerically Controlled machines show a great potential for surface structures. The aim of this research is to reveal this potential in the domain of folded plate structures. An interdisciplinary team investigates architectural, structural and mathematical aspects of folded plate structures built from cross laminated timber panels.

2.2. Structural Member

2.2.1. E K Mohanraj et. al. (2002): analyzed a single column is supporting structure, in which all other members are acting as cantilevers. To reduce the cantilever span for the structural beams converting two-third of the length as simply supported by providing the two ring beams and inclined beams. The structure is analysed and designed using STRAP (Structural Analysis Package), which is based on Stiffness Matrix method. Conclude that if maximum space utilisation is considered while planning and designing then it will surely serve its maximum serviceability.

2.2.2. Ambati Venu Babu et. al. (2016): Analysed a triangular shape building in which mono column situated at the edge of triangle not its centre & they found that a Single column structure is a critical one when it is being to an symmetrical and eccentric loading condition. since single column is supporting whole structure, all other members will act as cantilevers. To reduce the cantilever span for the structural beams converting two - third of the length as simply supported by providing the two ring beams and inclined beams. The structure is analyzed and designed using Staad pro (structural analysis package), which is based on stiffness matrix method. The above structure has been analyzed for various possible loading conditions and the critical has been selected for design purpose.

2.2.3. B.B. Babicki (1972): give detail about structural system & material used in the Westcoast Office Building is located in Vancouver Canada in a very picturesque setting and on one of the major arteries of the city connecting the downtown business core to the residential areas. This building has a total of 152,000 square feet of office area and covered parking accommodations for 200 cars. It was designed for Westcoast Transmission Co. by Bogue Babicki & Associates, Consulting Engineers of Vancouver and construction completed in 1970. The concept of the building were, the least interference with the natural setting and earthquake resistance since Vancouver is located on one of the severest earthquake zones extending from California to Alaska. The building in its final form has a 277 foot high concrete centre core 36 x 36 feet in plan area and accommodating 21 levels from foundation to top. Three Underground parking levels, equivalent of three levels of open plaza space, twelve levels of typical office floors, 110 x 110 feet in plan area suspended from the centre core above the plaza space plus, three levels within the core above the roof for mechanical and elevator equipment.

2.2.4. Badikala Sravanthi et. al. (2016): design and analysis of RCC structure supported on a single column is done in this project (figure 1). Cost Comparison is done between RCC single column and RCC multi column structure. This paper presents structural modelling, stress, bending moment, shear force and displacement design considerations for a structure and it is analyzed using STAAD Pro. Various steps involved in designing of RCC structure supported on a single column using STAAD pro and comparison of RCC single column and RCC multi column Structure. They conclude following:-

a) Single column structure has been designed successfully to withstand all loads including earthquake and wind load.
b) Single column structure is 20% more costly when compared with multi column structure.
c) Single column structure provides better architectural view and free ground space even though it costs bit more than multi column structure.

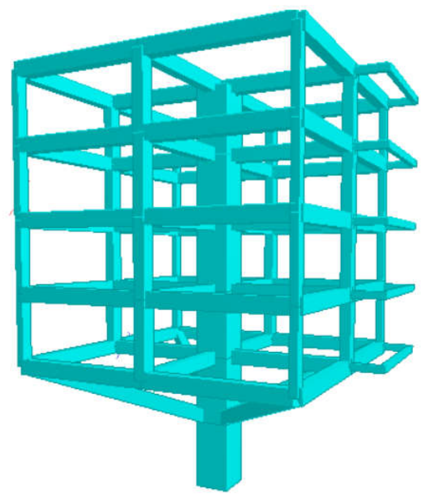

Figure 1. RCC Structure Supported on a Single Column

2.2.5. Madireddy Satyanarayana (2016): analyze and design of multi-storey building resting on the single column by using different code provisions. A lay out plan of the proposed building is drawn by using AutoCAD 2010 .The structure consist of ground floor plus five floors, He planned building as per Indian standard code provisions. The building frames are analyzed manually by Limit state method and give structural detailed for critical and typical R.C.C. members.

2.2.6. Donald MacLeod et. al. (2011): researched a technology in which mono-column is supported directly on the existing jacket pile at the sea bed and uses the platform's existing redundant pile capacity to economically extend the space available for the new compression facilities. A simple spigot interface between the mono-column and existing pile also negates the need for grouting, temporary fixings and any subsea intervention. Traditional approaches to increasing real estate on offshore platforms involve the installation of cantilevers or shoe horning equipment into inefficient spaces leading to extensive offshore hours and lengthy shutdowns. The critical design consideration for this structure is its ability to survive a ship impact scenario. To address this, the structure adopts technology developed for the transport of nuclear materials. Energy absorbing technology and analysis expertise have been utilized to create a 'crumple zone' to protect the new structure. This innovative mono-column structure by appearance is deceptively simple yet complex when it comes to balancing the design for ship impact, fatigue and extreme environmental loading. Many iterations have been undertaken to optimize the design as far as possible whilst keeping the structure free from components that are challenging to fabricate or costly to maintain. The final solution, has realised considerable cost savings and had a significant positive influence on the project economics thereby helping to extend production from a North Sea field that might otherwise have been abandoned sooner.

2.3. Structural Material

2.3.1. A. Braconi et. al. (2002): a multi-level pseudo-dynamic (PSD) seismic test programme was performed on a full-scale three-bay two-storey steel–concrete composite moment-resisting frame built with partially encased composite columns and partial-strength connections. The system was designed to provide strength and ductility for earthquake resistance with energy dissipation located in ductile components of beam-to-column joints including flexural yielding of beam end-plates and shear yielding of the column web panel zone. In addition, the response of the frame depending on the column base yielding was analyzed. Firstly, the design of the test structure is presented in the paper, with particular emphasis on the ductile detailing of beam-to-column joints. Details of the construction of the test structure and the test set-up are also given. The paper then provides a description of the non-linear static and dynamic analytical studies that were carried out to preliminary assess the seismic performance of the test structure and establish a comprehensive multi-level PSD seismic test programme. The resulting test protocol included the application of a spectrum-compatible earthquake ground motion scaled to four different peak ground acceleration levels to reproduce an elastic response as well as serviceability, ultimate, and collapse limit state conditions, respectively. Severe damage to the building was finally induced by a cyclic test with stepwise increasing displacement amplitudes.

2.3.2. Dr. P. Suryanarayana (2010): developed an approach Large floor area can be economically constructed adopting steel framework of columns, girders and flooring of reinforced concrete. The following conclusions are drawn from the study. LRFD methods are more comprehensive than ASD methods and result in economical design. Savings of order 11% for secondary beams and 16% for primary beams are achieved. Steel-concrete composite construction requires less number of secondary beams compared to limited continuity designs. Due to composite action, the size of steel sections can be reduced. Savings of order 22% for secondary beams and 15% for primary beams can be achieved. These savings are partially offset by the cost of shear connectors. It is concluded that safe and economic designs can be obtained by the LRFD method given in IS:800-2007 for steel frames.

2.3.3. T. Andres Sanchez (2011): developed steel-framed floor systems utilizing long-span metal deck have the potential of providing large column free areas with overall floor thicknesses approximately equal to concrete flat plates while typically imposing less dead load on the structure. The vibration serviceability of such floor systems is investigated in this paper. Two laboratory specimens, a full-scale mockup, and 13 in-situ floors were tested to measure their natural modes and responses to walking excitations. Natural modes determined using experimental modal analysis techniques or heel-drop test results. Response to walking was determined by measuring the maximum peak acceleration due to individual walkers traversing the floor. The natural frequencies for the laboratory specimens and mockup were in the range of those measured for typical composite framing systems where as all in-situ floors are high-frequency floors. The measured accelerations due to walking and subjective evaluations indicate that such floors will generally have adequate resistance to vibrations due to walking. Natural modes were determined using experimental modal analysis techniques or heel-drop test results. It is emphasized that LSCD designs must be evaluated during the project design phases.

2.3.4. Mahbuba Begum, et. al. (2013): investigated the behaviour of partially encased composite columns with high strength concrete. It's under eccentric and concentric axial loading tends to be complex because of the interaction of the concrete with the thin-walled steel section. When constructed with high strength concrete, developing numerical simulations of the response of these columns under load is particularly challenging. They conclude by the dynamic explicit solution strategy. The model is able to simulate the full behavioural histories of a variety of PEC columns tested under concentric and eccentric loading, with excellent accuracy. The interaction between the steel and concrete and their separation at the common interface due to the local instability of the flange was successfully modeled with the contact pair algorithm. The model provided good representations of the peak load, axial deformation at the peak load, post peak behaviour, and the failure mode observed in the test.

2.3.5. Dr. D. R. Panchal (2014): analyzed composite framing system consisting of steel beams acting interactively with metal deck concrete slab and concrete encased composite columns, has been as a viable alternative to the conventional steel or reinforced concrete system in the high-rise construction. However, in Indian context, it is comparatively new and no appropriate design codes are available for the same. Complications in the analysis and design of composite structures have led numerous researchers to develop simplified methods so as to eliminate a number of large scale tests needed for the design. In the present work, a simplified method of composite slabs, beams and columns design is used and software is developed with pre and post processing facilities in VB.NET. All principal design checks are incorporated in the software. The full and partial shear connection and the requirement for transverse reinforcement are also considered. To facilitate direct selection of steel section, a database is prepared and is available at the back end with the properties of all standard steel sections. The proposed computational method, for composite columns with a variety of steel sections encased in concrete and various concrete filled sections, is found to provide accurate results. For the analysis of a composite frame, a concept of the effective elastic bending stiffness of the composite section is proposed and calculations are carried out by moment distribution method using Microsoft excel sheet. Results obtained are found in good agreement with those obtained by using ETABS software.

2.3.6. M. S. Matsumoto (2012): studied on composite material used in high-rise structure and said that Nowadays, structural needs for ultra high-rise buildings are changing and expansion of planning flexibility is becoming significant. For example, long span girders for large workspace, altering column position in middle stories to achieve different use in height direction and great public atrium in lower stories that provides attractive free space. Moreover, high seismic performance is becoming more demanded which protects human life and maintains the function of the building under severe earthquakes. In order to achieve these needs, as one of technology, we have developed ultra high strength concrete filled tubular (CFT) columns that combine ultra high strength concrete with specified standard strength Fc150 N/ mm2 and ultra high strength steel material with tensile strength of 780 N/mm2 . In this paper, the outline of development of a ultra high strength CFT column is reported. Also, the structural design of the ultra high-rise building using the CFT columns is reported. By combining with response control systems, these members have elastic deformation capability suitable for satisfying high design criteria. In addition these members can achieve structural framing and architectural spaces with a high degree of freedom as a result of their large load bearing capacity, so it is considered that in the future their application to ultra high rise buildings will expand.

2.4. Multi-Storey Structure

2.4.1. Janakkumar M. Mehta (2017): Observed that the building height is more and more slender, and more susceptible to sway and hence dangerous in the earthquake. Such type of the building can be strengthening by providing an appropriate lateral load resisting system. In the seismic design of the buildings, reinforced concrete structural walls or shear-wall, act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. The properties of these seismic shear-walls dominate the response of the buildings and therefore, it was important to evaluate the seismic response of the walls appropriately. In this study the (G+17) storey building was analyze with different shear-wall configuration. The modeling is done to examine the effect of different cases on seismic parameters like base shear, lateral displacements, lateral drifts and model time period for the zone-V in medium soil as specified in IS: 1893-2002.

2.4.2. Pooja Liz Isaac et. al. (2017): proposed a structural design of tall buildings is governed by the action of lateral loads due to wind or earthquake. Lateral load resistance of a structure is offered by interior structural systems or exterior structural systems. Exterior structural system constitutes Diagrid, Hexagrid, Pentagrid and Octagrid Systems. Recently, Diagrid structural system is adopted in tall buildings due to its structural efficiency, superiority in aesthetic appeal and flexibility in architectural planning. Diagrids, Hexagrids and Octagrids contain triangular or diamond shaped modules, hexagons and octagons respectively, throughout exterior of structure and they don't have any external vertical columns. Due to inclined columns, lateral loads are resisted by axial action of the diagonal. A regular floor plan of 36 m x 36 m size is considered. ETABS V15 software is used for modelling and analysis of structural members. Twelve models are created collectively of Exterior Braced steel frame structure, Diagrid, Octagrid and Hexagrid buildings with regard to variation in their diagonal angles and module density. Equivalent static and Response spectrum analysis of these models have been carried out to examine their performance. A comparison of parameters Storey Shear, Storey drift, Storey displacement, Time period and Structural weight is done to determine the efficient and cost effective structure.

They found the Equivalent static and Response spectrum analysis of Diagrid, Hexagrid, Octagrid and Exterior Braced steel building were performed. The performance of Diagrid buildings modeled with different diagonal angle, Hexagrid and Octagrid with different module density and Exterior Braced steel structure under dynamic loading were investigated and the values of parameters Storey Displacement, Storey Drift, Storey Shear, Time Period and Structural weight were compared.

2.4.3. Erik Hallebrand et. al. (2016): investigated the Dynamic effects such as resonance frequencies and accelerations are considered. The variation in static results from reaction forces, overturning moments, deflections, critical buckling loads, forces between prefabricated elements and force distributions between concrete cores are investigated with different models.

Through investigations they found that when modelling a building, that are to be constructed with prefabricated concrete elements, the use of wall elements is a good way to create a model that represents the buildings global behaviour. This because they are time efficient, both in modelling and analyses, as well as providing reliable results. Hollow-core slabs are commonly used prefabricated slabs and span in one direction. In order to represent the load from these in a finite element model they can be modelled as a one-way floor load. This will provide a proper cumulative load calculation in order to design the foundation. For vertical and horizontal loads on a building, advantage can be taken to study each load-case separately. The force distributions and reaction forces due to vertical loading should be analyzed without the consideration of floor diaphragms. This because the floor diaphragms are very stiff and can thereby redistribute forces latterly between elements in a building, resulting in unwanted shear forces and misleading results. When analyzing horizontal load, however, the consideration of floor diaphragms are very useful.

3. Conclusion

1. For high rise buildings are more exposed to sway due to dynamic response of wind and earthquake loads. It is observed that resonance frequencies should be evaluated when designing high-rise buildings..
2. Large floor area can be economically constructed adopting steel framework of columns, girders and flooring of reinforced concrete.

3. The structural design of the ultra high-rise building using the CFT columns by combining with response control systems, these members have elastic deformation capability suitable for satisfying high design criteria. In addition these members can achieve structural framing and architectural spaces with a high degree of freedom as a result of their large load bearing capacity
4. Single column structure is a critical one when it is being to an symmetrical and eccentric loading condition.
5. Single column structure provides better architectural view and free ground space even though it costs bit more than multi column structure.

References

[1] Badikala Sravanthi, Dr. K.Rajasekhar, (2016) " Design Of A Structure Supported On Single Column", Pp In ISSN-2349-8439 .

[2] Venu Babu A, Et Al, (2016) "Design Of A Structure Supported On Single Column Office Building", International Journal Of Research Sciences And Advanced Engineering [IJRSAE] Volume 2, Issue 15, Pp:112-123.

[3] Madireddy Satyanarayana, (2016) "Design Of Multi Storey Building Resting On Single Column" IJRET Eissn: 2319-1163 | Pissn: 2321-7308.

[4] Anupam Rajmani, (2015) " Analysis Of Wind & Earthquake Load For different Shapes Of High Rise Building ISSN 0976 – 6316(Online) Volume 6, Issue 2, SSN 0976 – 6308 (Print), pp. 38-45.

[5] Dr. D. R. Panchal, (2014) " Advanced Design of Composite Steel-Concrete Structural element" Pp In ISSN - 2248-9622, Vol. 4, Issue 7(Version 2).

[6] M.S. Matsumot, Et Al, (2012) "Structural Design of an Ultra High-rise Building Using Concrete Filled Tubular Column with Ultra High Strength Materials" PP. 15 WCEE.

[7] Donald MacLeod, Tom Mathie, Graham Dunlop, and Sean Duvall, (2011) " Innovative Mono-Column Support Structure "PP. at the SPE Offshore Europe Oil and Gas Conference and Exhibition held in Aberdeen, UK.

[8] Morita, K., Keii, M. And Matsumoto. S, (2011) "Applications Of High Performance Structural Steels To High-Rise Steel Buildings" The 6th international Symposium On Steel Structure" (ISSS), International Journal Of Steel Structure, Pp.21-35.

[9] T. Andres Sanchez, M.S., E.I.T., Brad Davis, Ph.D., S.E., And Thomas M. Murray, Ph.D., P.E, (2011) "Floor Vibration Characteristics Of Long Span Composite Slab Systems", Structures Congress © Asce.

[10] A. Braconi et. al., (2008) " Seismic performance of a 3D full-scale high-ductility steel–concrete composite moment-resisting structure—Part I:Design and testing procedure" Published online in Inter Science Wiley.

[11] Hani Buri, et. al. (2008) "ORIGAMI – Folded Plate Structures, Architecture" Info Science EPF.

[12] Mahbuba BegumRobert G. Driver, M.ASCE and Alaa E. Elwi, M.ASCE, (2007) " Finite-Element Modeling of Partially Encased CompositeColumns Using the Dynamic ExplicitMethod", Journal Of Structural Engineering © Asce.

[13] Holger Eggemann, (2006) "Simplified Design of Composite Columns, Based on a Comparative Study of the Development of Building Regulations in Germany and the United States" Department of Architecture, University of Cambridge, Vol 1 1023-1042 Eggemann.

[14] YUN, hyun-do, CHOI, Chang-sik and LEE, li-hyung, (2004) "Earthquake performance of highstrengthconcrete structural walls with boundary elements" 13th World Conference on Earthquake Engineering, Vancouver,B.C., Canada.

[15] Eurocode4 (2004), "General rules for buildings design of composite steel and concrete structure",Committee Members of the European Union.

[16] E K Mohanraj, S Nisar Ahmad, A Gowri Sankar, Kongu Engineering College, (2002) "Analysis and Design Of An Office Building With Mono Column," PP. 27th Conference On Our World In Concrete & Structures.

[17] Babicki, B.B. "Westcoast Building Cable Suspended Structures Vancouver, B.C." PP 1972, Zürich, Schweiz, Ethz Zurich Library.

[18] IS 875:1987 (PART 2) code of practice for design loads (other than earth quake loads) for building and structures, new Delhi(India), Bureau of Indian standards.

[19] Is: 456-2000, Code Of Practice For Plain And Reinforced Concrete, New Delhi, Bureau Of Indian Standards .

[20] IS: 11384 (1985), “Code of practice for composite construction in structural steel and concrete”, Bureau of Indian Standards, New Delhi.