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Comparative Study of RCC and Steel Framed Multistory Structures: A Review

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A B S T R A C T

This research study focused and investigates about the RCC structures and steel framed structures which are popular and with growing demand in India. The study focused around multistorey high rise building structures. RCC is much costlier than steel framed structures for high-rise cases. This happened due to facts like increase dead weight, span restriction, low natural frequency and hazardous formwork. Steel framed structures offers safe over its design life span. The steel framed and concrete constructions best possible and simplest solution for heigh-rise buildings. In this paper we studied and ellobrates various results experiments and study performed by researchers considering RCC and Steel framed buildings under different loading conditions and building parameters.

Keywords: Multistorey Buldings, Seismic, RCC structures, Steel Framed Structures.

1.Introduction

Now a days, it is well know in India that to achieve the requirements of high rise building, steel framed structure is best suited for infrastructural growth rather than RCC. Recent studies and experiments performed by researchers suggested that steel framed structure considerably reduces the gravity load as compare to RCC. The compressive strength and application cost of reinforced concrete is higher than that of structural steel, pre engineered like modern systems, allowing the project to complete including fast erection of multi-story structural frames in lesser lead time. It is expensive and uneconomic approach to delay the construction at each phase floor by floor while concrete columns are cast. In highly seismic sensative countries like Japan, the superior earthquake resistant properties of composite beam-columns have been long recognized and have become a commonly used for construction in that region. It was therefore necessary to develop seismic design criteria for typically used Indian structural systems, to advance the use of this efficient type of modern construction practices.

1.1. Types of Structure

- RCC Structures

  Term RCC refers to “Reinforced cement concrete”. Concrete behaves better in compression than in tension. So to increase the tensile resistance capacity of structure, steel reinforcing barsare used in collaboration with concrete.
- Steel Structures

  When the Fabricated steel or Structural steel is used as a construction material for buildings, the term comes into picture is known as “steel structures”. According to indian standards, different type of steel shaped members are used in steel buildings like I-section, angle section, channel sections etc. Being a lighter material, it is very useful in earthquake prone areas . the members are created into different shapes and sizes in the factories according to requirements at site.

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- Composite Structures

  A member is said composite, when a concrete member and steel component like Steel plate, Isection etc. are used together in such a way that they experience transfer of forces and moments in them, in order to take full advantages of steel in tension and concrete in compression are utilized together to get best capabilities of both of these. This additionally is economical.

1.2. Eaethquake Zone

Bureau of Indian Standards [IS 1893 (Part I):2002], has grouped the country into four seismic zones, viz. Zone II, III, IV and V. Of these, Zone V is seismically the most active region, while zone II is the least. Broadly, Zone - V comprises entire north-eastern India, parts of Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Rann of Kutch in Gujarat, part of North Bihar and Andaman & Nicobar Islands. Zone - IV covers remaining parts of Jammu and Kashmir and Himachal Pradesh, National Capital Territory (NCT) of Delhi, Sikkim, Northern Parts of Uttar Pradesh, Bihar and West Bengal, parts of Gujarat and small portions of Maharashtra near the west coast and Rajasthan. Zone – III comprises Kerala, Goa, Lakshadweep islands, remaining parts of Uttar Pradesh, Gujarat and West Bengal, Parts of Punjab, Rajasthan, Bihar, Maharashtra, Orissa, Andhra Pradesh, Tamilnadu and Karnataka. Zone - II covers remaining parts of country.

2. Literaature Review

Harish Soundalgekar and Kshitij S Patil, (2023) In this paper the main endeavour was to deal with the comparative study of structural analysis between Steel framed and Reinforced concrete structures. Three-dimensional model of RCC and steel structure are analysed with the help of software ETABS and Staad Pro. This study shows comparison of various aspects of building construction for steel and RCC buildings considering various researches involve in this topic. According to the results, the deflection of the steel structure is much larger than that of RCC because steel is a ductile material and allows for greater deflection. If lateral displacements and vertical deflections are taken into account, the rigidity of reinforced concrete structures is higher than that of steel. It has been observed that the cost of building a steel structure is higher than that of an RCC structure. However, faster construction can mean that steel construction makes economic sense.

Md.Yaser and Ajith Kumar Dey, (2022) The primary objective of this paper was to compare the structural behavior of low, medium & high rise buildings situated in seismic zone-IV, with the RCC, steel & composite construction. Frame structure is either made of RCC, steel or steelconcrete composite sections. Their behavior will be analyzed by using the ETABS software & cost analysis of Beams & Columns is done in all three cases using MS- Excel software. Then all the results will be compared in order to find the economical building and better structural performance under equivalent static load analysis and response spectrum analysis. The main conclusion came out is that the composite construction is best in case of high rise buildings. As the comparison of steel , RCC & Composite frame buildings is done for 11, 21 and 31 story buildings, which conclude that composite frame Reponses better when subjected to earthquake loads in comparison with RCC & steel. Response Spectrum analysis give better results than Static analysis.

Jadhav Gorakhnath S, et. al, (2022) The present comparative study deals with inelastic behavior of RCC and composite structures. The pushover analysis is carried out using E-tab 15 and compare the various parameters like story drift, displacements etc. The reviews shows that, the composite structures are best suited for high rise buildings compared to that of steel and reinforced concrete structures. From the equivalent linear analysis it is seen that the story drift reducess appr. upto 49 %. As Compared with RCC. The story displacement is also reducess appr. upto the 9%. From equivalent linear static analysis. From pushover analysis it is seen that story displacement is decreases as compare to RCC. Also story drift of SRC –composite is considerably reduced as compared wiyh RCC. Overall response of composite structure is better than RCC structure i.e. composite structure produces less displacement and resists more structure forces.

Sayyed Faizuddin Hashmi and Hemant.B.Dahake, (2021) This paper presents a work done on seismic performance of reinforced concrete structure and composite structure of G+10 buildings in seismic zones III & IV. This paper focus on the R.C.C Structure and Composite Structure with their relative significance. The results are obtained on the basis of Story Drift, Story Displacement. The seismic performance of buildings having reinforced concrete structure and composite structure is comparable but the differences exist. Three-dimensional model of RCC and steel structure are analysed with the help of software ETABS 2018. From the analysis done on G+10 structure in zone III & zone IV conclusions made are, In zone III & zone IV story drift is coming out to be less for composite, column structure as compared to RCC column structure for G+10 modal. In zone III & zone IV story displacement is coming out to be less for composite column structure as compared to RCC column structure for G+10 modal. In zone III & zone IV self weight is coming out to be less for composite column structure as compared to RCC column structure for G+10 modal. Composite and Steel structure show to be economical. Composite structures are being more ductile, resist lateral load better than RCC structures. From the result it can be concluded that for low rise building and high-rise building composite structure gives best result than RCC frame under seismic analysis.

Raghuvaran Komati and Battu Jaya Uma Shanker (2021) Due to rapid growth of population, construction of high-rise buildings became predominant. Those buildings which are not designed against seismic excitation leads to heavy structural damage due to vibrations generated by earthquake at the ground level. For low-rise buildings, reinforced concrete structures are being used over many years due to their flexibility and cost-effectiveness. Reinforced concrete structures are no longer preferred for medium to high-rise buildings due to their heavy load, lesser stiffness and hazardous formwork.

Steel and composite frames are preferred for high-rise structures due to their higher flexibility and lighter weight. Composite frames are mostly preferred which enhances the stability and life of structures. Pushover analysis is a static non-linear approach which analyses the successive damage of the structure using ETABS. In this study, review of pushover analysis of different frames used for high-rise buildings such as RCC, steel and composite frames are to be discussed. Base Shear, lateral displacement of structure, time taken by structure to oscillate due to earthquake shaking and response of structure due to variation of number of stores are to be analysed. It is concluded that the steel and steel-concrete (composite) structure are the safe choice for constructing high-rise buildings due to flexibility, ductility than reinforced concrete structures. It was concluded that, as shear at bottom is considered, RCC structures performs better than steel and composite structures as it possesses higher dead load. Steel structures are found to be more effective than composite and RCC framed structures due to lesser weight and higher ductility of steel. Steel structures are used to resist the seismic forces for longer time than composite framed structures. It was concluded that the composite structure is costlier than the RCC and steel structures but it performs well in case of earthquake condition. The steel structure is the best and effective option than RCC structure but Composite structure performs effectively under seismic excitations.

Bhanu Prakash et. al., (2021) This study investigates about the composite structure is gaining more popularity in developing countries. For medium and high rise building in RCC structure is no longer economical because of increase dead weight, span restriction, low natural frequency and hazardous formwork. Steel and concrete composite structures are becoming more popular nowadays and safe over its design life span. After studying the journal papers, many researchers as said that steel is most universally useful and versatile material for engineers and construction purpose. Steel provides light weight structure in composite concrete steel structure. The dead weight of the structure can be reduced by using light weight material like pre cast aerated concrete walls, panels etc. Easily for alteration and expansion if necessary. Steel structure provide Rapid construction, highly durable, it gains strength without taking a time, biodegradable and recyclable, provide long span. It results in less health hazards, less waste, less energy usage, less emissions and better environmental work in low to high rise building.

Mitaali Jayant Gilbile and S. S. Mane (2020) In this paper, an industrial structure (PEB & CSB Frames) is analyzed and designed according to the Indian standards. Three models each for PEB and CSB are considered having different widths and a parametric study is carried out to access the performance of the models in terms of weight comparison, cost comparison and time comparison. In this study, an industrial structure (factory truss) is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007. The researches show that PEB structures are easy to design. These designs are efficient and results in speedy construction. These structures are more reliable than CSB. Hence the more research required for more outputs for design methods and reducing material in PEB structures.

Ankush Dod and Prof. V. M. Sapate (2020) During occurrence of earthquake various types of structural failure occurs in structure due to some weak points and this weak points arises due to creation configuration of structures such as discontinuity bin mass, geometry and stiffness of structure and this discontinuities are termed as Irregularities. In the Present project work an attempt will be made to study the effect of vertical Irregularity for RCC and steel framing for low medium and high rise construction. Comparative analysis will be done between this two framing material systems. After analyzing and studying various structural parameters of RCC and Steel building it is found that for same earthquake zone and same geometric configuration steel structures gives less magnitude of axial force and base shear as compared to RCC structures. While comparing displacement ad time period RCC structure shows lower values than steel structures. So from the analysis it is clear that if steel structures are used in vertically irregular zone special displacement control provisions are to be done. Even in low risk Zone and varying height irregular structure under dynamic loading Steel structures oscillates for more time than RCC structures. So steel structures should be avoid, and if used they can be properly braced to minimize time period. Results shows that steel structures in all height variation gives less dead weight and helps to reduce intensity of lateral earthquake forces. So, Steel structures should be used In case of Irregular buildings in low risk zones under dynamic loading.

Sumit Shah and S.Saranya (2020) In South Asian countries concrete is mostly used as construction material, especially for low rise structures. Still steel is not predominantly used in high rise structures. Besides, Reinforced Cement Concrete (RCC) and steel structures; composite structures can be built to get maximum benefit of the steel and concrete, as well to produce reliable and economic structures. In this paper comparative study of nine storey hospital RCC and steel building is carried out. For the modelling and analysis of RCC and steel structure ETABs software is used. Comparative study of different parameters like base shear, load carrying capacity, displacement, time period, axial force, and cost is carried out with RCC and steel structures. Final results illustrates that steel structures are more suitable for high rise structures, less time consuming and they are cost effective too.

G.Hemalatha et. al. (2020) In India concrete is commonly used construction material particularly in case of average and low-rise buildings. For high-rise structures steel is preferred. The material used in construction should be cheap, safe and easy handling. Each material used for construction has its specific advantages and disadvantages. Steel members are excellent in tensile strength & ductility although concrete members are good in compression & stiffness. This project compares between the RCC and steel structures in accordance to their structural performance and cost. In this project a G+5 building is

considered for analysis. Two different types of models of RCC, and Steel structures are created. These models are analysed for shear forces and bending moments using Etabs software. It has been observed that cost of construction for steel structure is more than RCC structure. However faster construction may brand Steel building economically viable. Further, Steel structures are expected to show better performance under earthquake due to higher ductility. According to the results, the deflection of the Steel structure is quite higher than RCC as Steel is a ductile material and allows a larger deflection.

Hemanthkumar.S.K and A.R.Pradeep (2020) Structural design is aimed to design a structure that fulfills its intended purpose during its intended life span and be adequately safe in terms of strength, stability, and structural integrity, serviceability in terms of stiffness, durability, etc., and be economically viable, aesthetically pleasing, and environment friendly. This paper presents the studies on the analysis and design of the steel warehouse structure. The optimum design of the structure is carried out using finite element software STAAD Pro. The analysis of the structure is carried out for suitable steel sections with different load carrying capacity. The steel quantity required for the structure is calculated. Finally along with material optimization, techno-economical design to achieve the reliable performance of the warehouse structure is carried out. The steel warehouse is analyzed for the respected loads acting on the structure as per the codes. The warehouse structure is analyzed for the different load combinations. The materials quantity is calculated for the optimized design of the structure. Time saving design with respect to computer aided design of structure (CADS).

Ishwor Thapa et. al. (2020) This paper deal with the comparative study of structural analysis between steel framed structure and reinforced cement concrete structure. Mass material & storey stiffness, base shear, storey drift ratio, centre of mass, centre of rigidity and displacement is determined and compared to delve into a conceptual clarity regarding material choice. Three-dimensional model of RCC and steel structure are analyzed with the help of software ETABS 2016v16.2.1. It is concluded that, Construction of structure with RCC consumes large amount of raw materials. Hence, the mass material for RCC is greater than for steel frame structure. Maximum storey stiffness was greater for steel than concrete. Base shear is considerably less for steel structure as compared with RCC, which gives better response during earthquake. Story drifts for both models are found within the permissible limit as specified by the code IS 1893(part 1):2002. Centre of mass was same for both and centre of rigidity was more for steel. Story displacement was more for RCC frame model than steel frame model.

Anil S. Savadi and Dr. Vinod Hosur (2019) In this work. The comparative study of R.C.C, Steel and Composite Structure for industrial building (G+2) is presented. The parameter considered are cost of beam, cost of column, node displacement, member deflection, maximum bending moment, maximum shear force is considered. Thus based on the analysis results discussed in previous chapter fallowing conclusions drawn. The axial force in R.C.C structure is higher than the Composite Structure. Composite Structures are more economical than the RCC and steel Structure. Mass of composite structure is less than RCC structure but more than the Steel structure.Speed of work and speedy erection facilitates quicker return on the invested capital and benefit in terms of rent. For the erection work labor requirement is very less in composite structure compare to RCC structure. Deflection in composite structure is more compared to RCC structure and less compared to steel structure. The maximum bending moment and shear force is more than the RCC structure and less than the steel structure.

Mayank B. Patel (2019) A G+5 structure of plan dimensions 21.2 m x 34.8 m has been analyzed, and cost per unit quantities are worked out. Though the cost comparison reveals that steel structure design is more costly, reduction in direct cost of steel structure resulting from speedy erection will make steel structure economically viable. Further, under earthquake consideration because of the inherent ductility characteristics, steel-concrete structure will perform than conventional R.C.C. structure. The axial forces, bending moment and deflections in R.C.C. are somewhat more as compared to the Steel structure. The seismic forces are also not very harmful to the Steel structure as compared to the R.C.C. structure, due to low dead weight. There is the reduction in cost of steel structure as compared to R.C.C. structure due to reduction in dimensions of elements. As the result shows Steel structure option is better than R.C.C. Because Steel structure option for high rise building is best suited. It is clear that the nodal displacements in steel structure, by both the method of seismic analysis, compared to R.C.C. structure in all the three global directions are less which is due to the higher stiffness of member in a steel structure to R.C.C. structure. Steel structure is more economical than that of R.C.C. structure. Steel structures are the best solution for high rise structure as compared to R.C.C. structure. Speedy construction facilitates quicker return on the invested capital and benefits in terms of rent.

Anurag Saraogi et. al. (2018) In this paper, we compare a G+4 building made of RCC and steel simultaneously. The building is built in an earthquake zone where the effects of earthquake is studied on the building with the help of STAAAD.PRO. The cost comparison of G+4 Building reveals that RCC structure is more costly, reduction in direct costs of steel structure resulting from speedy erection will make Steel structure economically viable. Further, under earthquake considerations because of the inherent ductility characteristics, Steel structure will perform better than a conventional R.C.C. and Steel structure, because of: Weight of Steel structure is quite low as compared to RCC structure which helps in reducing the foundation cost. Steel structures are more economical than that of R.C.C. structure in the long run. Speedy construction facilitates quicker return on the invested capital & benefit in terms of rent. Steel Structure is more cost effective than RCC Structure. Steel structure is also portable. Steel structure is recyclable as well.

Tolga Celik and Saeed Kamali, Multidimensional (2018) This study is aimed at raising the knowledge about the technical features of cold-formed steel members as well as advantages of lightweight steel structure in comparison with reinforced concrete. To fulfil this aim, a case study was conducted to compare lightweight steel structure with reinforced concrete structure in different points of view in detail. From the case study, it is found out that the building total covered area and mass designed by reinforced concrete structure are 2.6% larger and 9 times greater than the lightweight steel structure respectively. It was also concluded that the total cost (indirect and direct) and construction duration for the reinforced concrete structural frame are approximately 17.7% and 70.9% respectively higher than constructing the lightweight steel structural frame. It is observed that total covered area of the

villa designed by reinforced concrete construction is 2.6% larger. Moreover, total mass of the villa designed by reinforced concrete construction is 151.7 tonnes making it 9 times greater than the total mass of the villa designed by lightweight steel construction that is only 16.9 tonnes. For that reason, it is concluded that in case of any earthquake impact of the seismic activity will be 6 times greater for the villa designed by reinforced concrete.

Jyothi D N (2018) In this project a G+2 building is considered for analysis. Three different types of 3D and 2D models of same building are prepared using stad Pro software. The different types of models are RCC, and Steel structures. These models are analysed for shear forces and bending moments using stad Pro software. The results obtained from each of the model are compared with each other to determine the best construction material. it is conclude that steel structure is more resist as compared to the normal concrete structure . A building constructed using steel has less dead load on it, even the beding moment and shear forces acting are less as determined in this work . It has high strength per unit mass. Hence even for large structures, the size of steel structures elements is small, saving space in construction and improving aesthetic view. Speed of construction is another important advantage of steel structure. Since Standard sections of steel are available which can be prefabricated in the workshop, they may be kept ready by the time the site is ready and the structure erected as soon as the site is ready. Hence there is lot of saving in construction time.

Mohd Tauseef and V.G.Meshram (2018) A framed structure of G+7 MIDRISE structure of 27 meters was considered and designed on Staad pro V8i to get results of a few important features like storey drift and column node displacement. A comparison is done with same frame with different materials i.e. steel, r.c.c and wood. Here in this part-1 we majorly study the lateral effect on structures and later part we may discuss the forces like moment , torsion etc. Joints of wooden structure will also be discussed in later part. It is concluded from study that Drift and node displacement initially propagates to higher rates at about 9m to 12m height because of effect of lateral loads since the base is fixed, thus we can say that the effect due to force takes some length to show its effect. Node displacement at top i.e. maximum increases much higher at corner to intermediate than from intermediate to centre. Steel due high ductile nature has higher value of both drift and node displacement than to its counterparts R.C.C. and Wood. R.C.C shows most promising in lateral behaviour having low storey drift and node displacement values closely followed by wooden structure which also shows promising results. Storey drift varies about 10%-15% and node displacement from 5%-10%, thus backing the above point of close lateral behaviour of R .C.C and Wood can be ascertained.

Isha Bedi et. al. (2017) Paper proposed to analyze and perform acomparative study of RCC Frame Structures using Staad.Pro, ETABS, and SAP. From the proposed research analysis we conclude that Staad.Pro is much more efficient. The values of force derivative are low as Compared to ETABS and SAP. The maximum the value of Force derivative will result in the maximum difference between the values of Staad.Pro, ETABS, and SAP. The present trend is to adopt reinforced concrete for bridges of small, medium and long spans resulting in aesthetically superior and economic structures in comparison with steel bridges. Due to thedevelopment of modern concrete, the desired properties of concrete such concrete strength and durability can be achieved for any type of construction but the quality and the performance of RCC are very important. We proposed to analyze and perform acomparative study of RCC Frame Structures using Staad.Pro, ETABS, and SAP. From the proposed research analysis we conclude that Staad.Pro is much more efficient. The values of force derivative are low as Compared to ETABS and SAP. The maximum the value of Force derivative will result in the maximum difference between the values of Staad.Pro, ETABS, and SAP.

Bhavin H. Zaveri et. al. (2016) This paper shows comparison of various aspects of building construction for steel, RCC as well as composite buildings considering various researches acted on this topic. It is concluded that the factors which should be considered to decide structural suitability are Seismic performance of the structure, Deformations Resultant Forces and Moments Cost Weight Fire performance. Paper also concluded that Overall response of composite structure is better than RCC structure i.e. composite structure produces less displacement and resists more structural forces. Composite structures are best solution for high rise buildings and they are resulted in speedy construction. Steel option is better than RCC but the composite option for high rise building is best. Steel has excellent resistance to tensile loading but prone to buckling and concrete gives more resistance to compressive force. Steel can be used to induce ductility and concrete can be used for corrosion and fire protection. Composite structures are resulted into lighter construction than traditional concrete construction as well as speedy construction. So completion period of composite building is less than RCC building.

3. Finding from Literature Review

RCC Building structures involves a large variety of raw materials. Therefore, the quantity and volume of the RCC material is larger than for steel frame construction. Steel framed structures are suggested by researchers expected to have better seismic performance comparative to RCC structures due to high ductility. Axial forces are also lower in case of steel framed structure, it is due to the lighter weight of the steel structure compared to the RCC structure. Literature suggests that the deflection of the steel structure is much larger than that of RCC because steel is a ductile material and allows for greater deflection. If lateral displacements and vertical deflections are taken into account, the rigidity of reinforced concrete structures is higher than that of steel. The steel structure has also significantly less torsion a0nd we can achieve larger spans with smaller cross-sections. Shear at the base is much less in steel

structures compared to RCC, which provides better response during an earthquake. It has been observed that the cost of building a steel structure is higher than that of an RCC structure. However, faster construction can mean that steel construction makes economic sense.

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