Comparative Study on Analysis and Design of Steel Building and Conventional RC Building

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Abstract:
The study of this paper reviews to analysis and design of steel members or sections to be used in construction of apartment building in steel structure, and its comparative study with conventional rc building. Such newer techniques are studied to perform more fast and precise work on field. In the present work a G+4 storied apartment building whose ground floor is considered as parking floor, is situated in second tier city of Nasik. Nasik city belongs to the earthquake zone-III. As ground floor is considered as parking floor rest other floors have same plan comprising of 8 2BHK flats on each floor. As 4 storied building is earthquake dominating so keeping the wind analysis deprived and analyzing the building for various combinations of earthquake loads. Provision of IS: 1893(Part 1)-2016 is reviewed using commercial software for the analysis of models. As earthquake forces are associated with inertia, they are related to mass of the structure and so reducing the mass inevitably leads to lower the seismic forces. The design work is carried out using IS: 800-2007and IS: 456:2000 for steel and RC work respectively. This study comprise of comparison of structural parameters such as reactions, moments, shear force, displacements, story drift, etc. at various junctions of both buildings. Structural Stability of both building will be compared to get the clear idea about the behavior of the buildings under earthquake conditions. As the steel buildings are at risk of fire, so fire provision is studied. The consumption of structural steel in construction of residential and commercial building is very low in India as compared to many other developing countries in the world. Experience of other countries which selects structural steel as core/leading material indicates that it has many positive factors such as inherent strength, is biodegradable and recyclable.

Keywords: Bending Moments, Biodegradable, Comparative Study, Displacements, Earthquake Loads, Shear Force, Story Drifts, Structural Stability, Recyclable.

I. INTRODUCTION

A. BACKGROUND:
India is a country which is rapidly flourishing in different sector. Out of which Infrastructure is one of the important sector. But when discussion is specifically about buildings it comprises of industrial, commercial and residential buildings. Industrial buildings are mainly constructed in steel or PEB structures while residential and commercial are constructed in RCC. In surrounding locality most of the building structures lies under the category of low rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical. But since the population is growing exponentially and the land is limited, there is a need of vertical growth of buildings in coming future. Steel is one of the most widely used materials for building construction in the world. Its inherent strength, toughness and high ductility are the characteristics which make it ideal to use it for building construction. When compared to other materials, steel has the highest rate of recyclability and recent research in earthquake regions shows that steel is the most reliable structural material against seismic loads. Its comparative study is to evaluate weather steel structure is feasible in terms of structural performance, construction time, durability, etc.

1). Conventional RCC System:
The design of housing and residential building is influenced by many factors, including durability, long life and aesthetics. Presently the method which predominantly used in surrounding is Reinforced Cement Concrete (R.C.C.). This conventional method of RCC structure is sturdy and durable, but in rural or some semi-urban localities people compromises with the quality of concrete which actually needs to be used. If it happens so, building in its design life lacks in serviceability. Speed of construction is also one factor of RCC. An over dependence on concrete is alarming to environment. Once the building life is completed it is demolished and the remaining waste concrete is non-degradable and cannot be recycled. So it is important to find alternative options.
II. OBJECTIVES

1. To perform structural analysis and design G+4 storied apartment building in steel structural system and its comparative study with conventional RCC structure.
2. To study the behavior of steel structure against dead load, live load, seismic load and their various combinations.
3. To study the variation in results of both structural systems and evaluating it to get satisfactory outcomes.
4. To study comparison of both the systems in aspect of structural performance, construction methodology and economy of project.

III. METHODOLOGY

To conduct the intended research work, architectural layout plan of G+4 story residential (apartment) building has been prepared. Following the plan, rc structure with beam supported two-way and one-way slab floor system is formed. Again following same plan, steel structure with steel girder-beam floor topping rc slab on corrugated steel deck is formed. Hollow rectangular sections are used as steel columns. Then three dimensional structural modeling and static and dynamic analysis have been performed using commercial software for the two types of structural system. Loads are assigned as per different parts of IS 1893. Load combinations are generated accordingly. From analytical results, RC structure is designed using limit state of design method as per IS 456:2000. Steel structure is designed as per IS 800:2007, IS 806:1968, IS 808:1989, IS4000:1992. Complete construction cost excluding electro-mechanical cost has been prepared. Comparison of, structural behavior, construction method, and other related parameters have been prepared to evaluate better/ effective structural system for the building used for this research.

IV. STRUCTURE DESCRIPTION

A. STEEL BUILDING:

Structural steel building as per the name suggests that ‘structural steel’ is major component/construction material of this building. Structural steel is generally taken to include a wide variety of elements or components used in the construction of buildings; they include beams, girders, column sections, plates and purlins. Many of these elements are made from standard hot rolled sections, cold formed shapes or made up from plates using welding. These components are joined at connections using plates, structural components, welding or fasteners. A variety of steel types are used to produce these structural elements, plates and other components, depending on the intended use, cost and weight of the structure and corrosion resistance.

When discussion is on different components of steel building which helps in ideal behavior and load carrying of building, comprises of columns, stanchion, beams, girders, slab systems, etc. In its simplest terms in steel frames, similar to the other systems, the vertical load carrying structure comprises a system of vertical load carrying columns and other elements interconnected by horizontal beam elements which support slab systems. The resistance of lateral loads is provided by column-to-column beams or primary beams, secondary beams and slab systems.

1). Column / Stanchions:

Usually universal columns, standard hot rolled sections or rectangular and circular hollow columns are used for the vertical load transferring in the steel structures since they provide the easiest connection details. According to them, rectangular and circular hollow columns have better stability and therefore they are preferred prior to other options of columns. In multistory structures the dimensions of the steel columns can easily be kept constant with or without changing the thickness of member.

Columns provided in steel structure building are the hollow rectangular sections from Tata Structura. The size of column for its capacity is decided for effective height of 3m. Column splicing connection will be provided at the half floor height that is centre of floor-to-floor height. This leads to form a pure shear connection.
2) Beams and Girders:
Members that carry transverse loads are beams. The structural steel deck floor construction generally consists of secondary floor beams in-situ concrete slab. The most efficient floor plan in steel structures is in rectangular shape. The secondary floor beams which are closely spaced at the distance of about a meter are supported by primary beams. These primary beams are usually of rolled sections but can often take the form of castellated beams, fabricated plate girders or taper beams because of heavy loading, deeper construction and the possible need for service penetration.

3) Slab Systems:
The most widely used construction practice for slab systems is metal decking concrete slab defined Deck Slab/Composite Slab. Composite slabs are commonly used in different types of structures such as commercial, industrial, health and residential building due to the speed of construction, less weight, structural stability, shallow construction, sustainability, and a general structural economy that can be achieved. As the concrete and steel deck sheet usually does not bond perfectly, the composite action may not be complete and during the vertical movement (uplift) may occur due to lack of bond between the interfaces in the vertical direction. At the interface between concrete and deck sheet, the transfer of horizontal shear is ensured by the bond between these materials for the better composite action. The bond can be achieved by mechanical interlocks and chemical glues. Mechanical bond may be achieved by providing embossments on deck sheet, a common practice of providing shear studs. These studs are poked from upper face of deck sheet and connects deck sheet with upper flange of supporting beams.

4) Connections:
Connections are required to join individual members of the steel structures together to ensure composite action thus to transfer axial loads, shear, moment and torsion from one component to another. The design of connections between individual frame components is the most important aspect of structural steelwork for buildings. There are several methods of connecting steel members. The selection of a particular connection system should be governed not only by its capability to support the applied load, but also by the ease of connection to other components.

a) Bolting, Riveting and Welding:
Steel sections can be fastened together by rivets, bolts, and welds. Although rivets were used quite extensively in the past, their use in modern steel construction has become almost obsolete. Bolts have essentially replaced rivets as the primary means to connect non-welded structural components. It is generally cheaper to make a bolted joint than a welded one (particularly on site) so a designer will usually choose bolted work for both site and workshop with some shop welding where warranted by engineering design. According to the literature, site welding is utilized where the full strength of a member must be used at a connection and where tolerance, geometry or aesthetics require welded connections. In externally exposed work, welding is often preferred to avoid rainwater penetrating behind splice plates on exposed steel. High strength friction grip (HSFG) bolts work in much the same way. The bolt is tightened to some predetermined stress and it is this prestress which holds the two components together by friction. HSFG bolts are made from quenched and tempered alloy steel in order to obtain a high yield point combined with good ductility. Welding is perhaps the most important process used in the fabrication and erection of structural steelwork. It is used very extensively to join components to make up members and to join members into
assemblies and structures. Welding can save costs and reduce member sizes by dispensing with the need for brackets and plates at connections and by allowing the use of the whole cross-section of a member by eliminating holes for bolts. Whatever the process, all welds should comply with two requirements as follows:

- Ideally there should be complete continuity between the parts to be joined and every part of the joints should be indistinguishable from the parent material. In practice, this is rarely achieved, though welds giving satisfactory performance can be made.
- The joint materials should have satisfactory metallurgical properties, though poor welding practice can affect the end result.

Figure 6. Bolted Connection (Beam-to-Beam Connection)

B) Joinery:
Joinery will include details of two different connections which includes, ‘Welding’ and ‘Bolted’ connections. For this type of building welding will fully operate at fabrication plant and on the other hand bolting will be done at actual site as well as at fabrication plant. Submerged Arc Welding is one of the types which are preferred at large plant, where the fabrication work is on large scale. This type has great range of electrode strength and is low hydrogen process. There are various advantages for which this method is used are high deposition, deep weld penetration, sound welds, high speed welding and the weld produced is uniform, ductile and corrosion resistant. This process is a mechanized process so the human errors are eliminated. Welds done are furnished and healthy. ‘Bolted connections’, this type will be performed at actual site. Advantages of preferring bolted over other type are simple tools, less noise, quick fabrication and connections supports loads as soon as bolts are tightened. High Strength Friction Grip (HSFG) bolts will be used for this building. In HSFG bolts there are two commonly available grades i.e. 10.9 and 8.8. Bolts of grade 8.8 will be used at site. Ultimate tensile strength of the bolts will be indicated by first digit i.e. 8 (800 MPa), and the yield tensile strength will be indicated by remaining digit i.e. 0.8 (640 MPa).

Figure 7. Welded Connection (Submerged Arc Welding)

C) Construction Phases:
The construction process of steel building is typically divided in various phases which comprises of various phases as follows:

i) Planning and Designing
ii) Construction of steel frame foundation
iii) Fabrication of built-up beams and H-frame.
iv) Erection of steel frame at actual site.
v) Placing of floor systems.

As the name derives this first phase comprises of all planning, designing and the documentation work which is required at pre-construction stage. The work in this phase is similar for steel and conventional rc building. Whole construction work up to ground or plinth level is in RCC. Work of this phase will start as soon as first phase is complete. The interesting thing is that as soon the first phase will get complete second and third phase will start simultaneously. It will be an ideal condition if both second and third phase wraps nearly on same time. Fabrication phase includes construction of built-up beams and forming H-frame. As the beams used will be built-up beams from plates this would be one of the major work at fabrication plant. And secondly all individual members will be forming an H-frame to ease the work at site. With this column and beam will we welded with the seat angles and cleat angles which will help to place the secondary beams on site. Manufacturing the H-frame at plant will form furnish and sound connections. The maximum size of the H-frame is calculated and studied for our building plan so that it should not create any issue in transportation. The next phase consist of erection of steel frame. The transportation and the erection work will run simultaneously. As the material will reach on site the erection work will progress. Then the last phase of construction process will start i.e. construction of floor systems. Floor system will initially require deck sheet and shear studs. From the above content as we get rough idea that this type of building can be constructed and brought in utilization in less period of time. As speed of construction is fast it can used for any government scheme which is trying to provide shelter for the needy peoples.
V. PROBLEM DESCRIPTION

The proposed work of project includes a residential building at Nashik to be analyzed and designed for comparative study. Below shown is a 3D model of analysis in commercial software and the architectural plan of a typical flat as rest others are similar to it.

![3D Model in Software](image1)

![Typical Plan of A Flat](image2)

![RCC Beam Layout for Typical Flat](image3)

VI. ANALYSIS REPORT

The apartment building is modeled in commercial software. This building is modeled for two different types of structural systems and the results of analysis are described and are compared between.

A) BASE REACTION:

After analyzing the model the base reaction for different combinations are obtained and from that the maximum value of reaction are considered for the design of the column and footings. Graph below has reaction in kN on Y-axis.

![Base Reaction Comparison](image4)

B. BENDING MOMENT:

After analyzing the model the bending moments for different combinations are obtained and from that the maximum value of bending moments are considered for the design of the beams and connections in steel structural systems. Comparison graph has story levels on X-axis and bending moment in kNm on Y-axis.

1) Grid B:

![Bending Moment Comparison](image5)
2) Grid 2:

Figure.14. Bending Moment Comparison

C. SHEAR FORCE:
After analyzing the model the Shear Force for different combinations are obtained and from that the maximum value of Shear Force are considered for the designing of shear reinforcement in RCC and connections in steel structural systems. Comparison graph has story levels on X-axis and shear force in kN on Y-axis.

3) Grid B:

Figure.15. Shear Force Comparison

4). Grid 2:

Figure.16. Shear Force Comparison

D. DISPLACEMENT:
Maximum displacement of the building is obtained from the displacement at tower level, at that level displacement in three different directions is be compared. As we known that more the displacement is less is the stability of the building, in that way the graph will be studied. Comparison graph has different structural systems with 3 different axis details on X-axis and displacements in mm on Y-axis.

E. STORY DRIFT:
As per Clause 7.11, IS1893 (Part1):2016, the storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height. Comparison graph has different structural systems on X-axis and displacements in mm on Y-axis. Here 5th, 6th and P denote terrace, tower and parking respectively.

VI. FIRE PROVISION
In steel structure fire protection systems are designated to protect the structure from fire for a specified amount of time. Fire provision results in integrated package of measures designed to achieve maximum control and limiting the consequences of fire. It may consider warning, access to fire services and escape in terms of structural response. Various fire protection systems are available to be used as follows:

i) Boards and Blanket Fire Protection Systems.
ii) Intumescent Coating Steel Structure Fire Protection Systems.
iii) Sprayed Cementitious or Gypsum Based Coating.
Out of these three available options we will prefer first system i.e. Board fire protection system. This kind of protection uses plaster boards or boards made of mineral fiber, calcium silicate, gypsum plaster, or vermiculate fixed around the exposed parts of steel members. Calcium silicate boards are more expensive than gypsum boards. This type of fire protection system is widely used due to several reasons such as: it is clean, cost effective, water resistant and can be applied to non-painted steel members. They are usually glued or screwed to metal or wood framing which are fastened to the steel members. The number and thickness of layers can be easily adapted to the particular application. These systems are easy to apply and effective. Also, the steel member does not require any preparation prior to applying the protection. The boards create an external profile which is aesthetically pleasing. The thickness of the board is dependent on the material type used for board production and specified fire rating needed. But these boards are inflexible to use around complex details such as connections. A ceramic fiber blanket may be used as a more flexible insulating barrier in some cases. Some board products are soft or brittle and are susceptible to mechanical damage. Furthermore, boarded fire protection system is divided into main types namely: heavy weight and lightweight boards. The former is appropriate for the case where aesthetic view is major concern because it is in harmony with aesthetic finishes. However, the lightweight board is suitable for the case where aesthetic appearance is not important since it is not compatible with decorative finishes. Board fire protection system is capable of resisting fire for maximum four hours.

The advantages of Board and Blanket Fire Protections Systems are as follows:

i) It is suitable for members which are visible. Also, a range of surface finishes and colours are available.
ii) The thickness of insulation is guaranteed.
iii) It offers clean and dry fixing and hence will not disturb other operations.
iv) No preparation of the steel surface is required prior to applying this kind of fire protection.

VII. ADVANTAGES

Compared to the conventional RCC building structure, the new steel building structure has below enlisted advantages:

i) Steel building structure is light weight, high intensity and good seismic performance.
ii) The uniformity in the quality of structural steel used for construction.
iii) Steel building structure has quick construction speed and investment recovery is faster.
iv) Steel building structure is easy for large scale production.
v) In steel building structure architectural space decorations are varied.
vi) Steel building structure is environmentally protected and energy saving.
vii) Steel building fireproof performance is good.

VIII. CONCLUSION

On the following work carried out we conclude that,
1. Steel structures are expected to show superior performance under earthquake due to high ductility than the conventional RCC structure.
2. Axial forces are lower in steel structure due to lower weight of steel structure compared to RCC structure. Due to this the reaction obtained in steel is lesser than RCC, which gives better response during earthquake conditions.
3. According to the results of analysis when maximum displacement and story drift is compared it is quite higher in steel structure than in RCC. This shows that RCC is more durable and sturdy.
4. Bending moment and Shear force in beams of RCC structures is more as compared to that of steel structures.
5. Preferred boards fire protection a system simultaneously helps the building for resisting fire cause and hides all the exposing structural members.

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IX. REFERENCES


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