Comparative Study on Different Steel Structural System for Lateral Load Resitance

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***Abstract*:- Structures are designed for the loads, which are expected to act on it during its design life. Various loads to be considered in design as per the functionality of the structure are prescribed by national and international codes/ guidelines. Vertical and lateral loads are the major types of loads acts on the structures. Choosing the appropriate structural system, considering both structural requirement and economy is foremost and important step. In this study, the effectiveness of various structural systems for lateral loading resistance in steel buildings is assessed. The study is limited to steel planar frames. In this study, 2D structural frames modelling based software STAAD. Pro V8i will be used to generate and analyze two-dimensional frame models for the assessment of the relative effectiveness of the lateral load resisting systems under the effect of lateral and vertical loads. In this study, four different structural frame configurations are considered., i.e., Case -1 Fixed base with shear connected beam, Case – 2 Pinned bases with moment connected beam, Case – 3 Pinned with bracing system, Case – 4 Pinned with shear wall system are used. Each Case consist of different frames with varying number of floors and bays. The designs are carried out as per clauses of IS 800. The designed structures are then compared in terms of the structural steel quantities required and most economical system for each frame configuration is suggested. However, the RCC quantity required for the shear walls are not considered in the comparison**

Keywords: Steel structural system, Support condition, Lateral resistance systems, Bracing, Shear wall, STAAD.pro

1. INTRODUCTION

Nowadays, the Structural systems for residential, commercial or any other purposes have a great diversity. It was variety depends upon a number of points such as client's choice, design consideration, architectural perspective and other factor related to the application. For conventional output, a simple shaped structure has been chosen for the research purpose. As the research deals with different structure system i.e., shear wall and steel bracing systems, the main frame has been kept same in all case. Constant height, constant area, constant exposures in all sides and materials with same properties are the main features of the considered structural frame.

2. NEED FOR THIS STUDY

The need for this study is explained as follows

- Comparative study on different steel structural system for lateral load resistance Performance evaluation needs to be carried out for The designed structures are then compared in terms of the structural steel quantities required and
- most economical system for each frame configuration is suggested.

3. SCOPE FOR THIS STUDY

The scope of this study is explained as follows

- It helps Choosing the appropriate structural system, considering both structural requirement and economy is foremost and important step.
- The effectiveness of various structural systems for lateral loading resistance in steel buildings is assessed. The study is limited to steel planar frames.

4. OBJECTIVE OF THIS STUDY

The objectives of this study is as follows

- To find the performance point and to extract the bending moment, shear force and deflection corresponding to the performance point.

5. PROPERTIES OF FRAMES

In these studies, considering simple frames which consist beam and two column and considering different support condition. Simple frames connecting different Bay and Stories and those material and geometry properties are mentioned below:

Table 1: Properties of frame

Structural Element	Properties
Beam Length	8 m
Column Length	4 m
Floor Height	4 m
Max. Number of bays in frames	5 Nos
Max. Number of Stories in frames	20 Nos
Bracing pipe Length	8.94 m
Shear Wall Thickness	230 mm
Shear Wall width and Height	4m x 80 m
Beam Material	UB Section
Column Material	UC Section

Following points shall be noted while doing the load combinations:

- For structures which are supporting more than one equipment, only one equipment shall be hydro tested at a time.
- Where wind load is the main load acting on the structure, no increase in the permissible stress is allowed.
- Earthquake is not likely to occur simultaneously with maximum wind.

Displacements:

The limiting permissible deflections for structural steel members shall be as specified in Table 6 from IS: 800. The limiting permissible vertical deflection for RCC members shall be as per IS: 456. 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 storey height. For RCC structures, under transient wind load the lateral sway at the top shall not exceed 0.002 time the height of the building.

Computer Programs:

Following computer program is used for analysis and design.

- STAAD.Pro V8i: All analysis and design work related with structural steel shall be carried out using STAAD Pro V8i.
- Limit State Method of design as per IS: 800 shall be followed in the design of new steel structures unless otherwise specified elsewhere in this document for special structures.

6. COMPARATIVE OF DIFFERENT STEEL STRUCTURE:

Introduction:

There are different structures are considering for steel structure based on its load transforming, in these studies considered four cases for comparative study. Structural connections are used to hold connecting members in static equilibrium, and ensure adequate transfer of forces from one member to the other at structural joints. They should be able to provide adequate resistance to forces acting, without compromising the permissible strength of the connection. for static equilibrium condition.

- sum of all forces acting at the joint are zero (thus the components, are sum of vertical forces are zero, and sum or horizontal forces are zero)/
- sum of moments, and moment of forces at the joint are zero.

These are the basic criterion necessary to counter the shear and moment at a specific structural joint, and are measured with specific engineering standards for such structural works.

Shear Connection:

A beam bolted to a column. It is a shear only connection because the beam flanges are not rigidly connected to the column. Note the gap shown between the bottom flange of the beam and the column.

Moment (Rigid) Connection:

A welded beam to the column. The beam flange welds transmit full flange strength to the column. The shear tab, welded to the column, and bolted to the beam web, supports the beam until it is welded and offers permanent shear resistance.

These studies consider four cases and mention below:

- Case A - Fixed Base and Shear Connected Beam
- Case B - Hinged Base and Moment Connected Beam
- Case C - Hinged Base, Shear Connected Columns and Beams with Diagonal Brace
- Case D - Hinged Base, Shear Connected Columns and Beams with Shear Wall.

7. FIXED BASE AND SHEAR CONNECTED BEAM:

In this case - A, the frame consists of a beam as 8m which is supported by two columns as 4m each and bottom condition of columns are fixed in the bases at the both and a beam is consider as shear connected beam which is doesn't allowed moment transfer to column directly and transferring shear force to column.
Frame consist external loads which are axial and lateral loads 100kN and 10kN respectively. Axial load act on frame which on a beam mid span and lateral load act on a column top horizontal direction. In this case material used as universal material for beam and column.
Due to axial and lateral loads act on frame, the frame tends to sway higher than other cases with in permissible, the selection of material depends upon as per permissible defection.

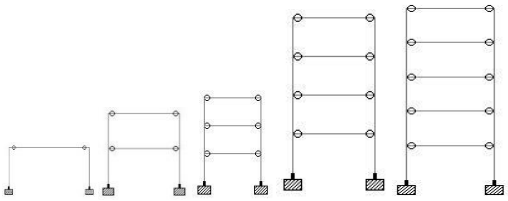

Fig 1: Fixed baes and shear connected Single Bay system

8. HINGED BASE AND MOMENT CONNECTED BEAM:

In this case - B, the frame consists of a beam as 8m which is supported by two columns as 4m each and bottom condition of columns are Hinged in the bases at the both and a beam consider as moment connected beam which is doesn't allowed moment transfer to column directly and transferring shear force to column.
Frame consist external loads which are axial and lateral loads 100kN and 10kN respectively. Axial load act on frame which is on a beam of mid span and lateral load act on a column top horizontal direction. In this case material are used as universal materials for beam and column.
Due to axial and lateral loads act on frame, the frame tends to sway is less than Case – A, with in permissible, the selection of material depends upon as per permissible defection.

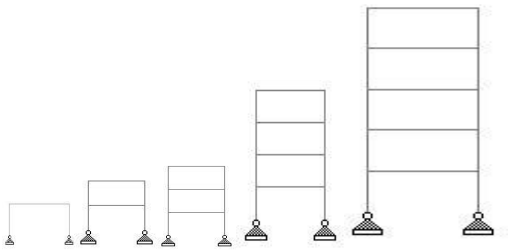

Fig 2: Hinged base and moment connected Single bay system

9. HINGED BASE, SHEAR CONNECTED COLUMNS AND BEAMS WITH DIAGONAL BRACE:

In this case - C, the frame consists of a beam as 8m which is supported by two columns as 4m each and bottom condition of columns are Hinged in the bases at the both and a beam is consider as shear connected beam with diagonal brace which is resist lateral loads and its doesn't allowed moment transfer to column directly and Transferring shear force to column.
Frame consist external loads which are axial and lateral loads 100kN and 10kN respectively. Axial load act on frame which on the mid span of the beam and lateral load act on the column top horizontal direction. In this case material are used as universal materials for beam and column.
Due to axial and lateral loads act on frame, the frame tends to sway less than other cases with in permissible due to provide bracing, the selection of material depends upon as per permissible defection.

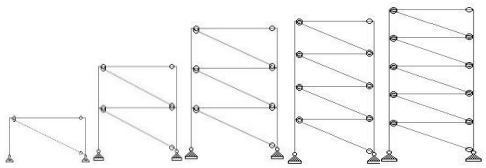

Fig 3: Hinged Base, Shear Connected Columns and Beams with Diagonal Brace Single bay system

10. HINGED BASE, SHEAR CONNECTED COLUMNS AND BEAMS WITH SHEAR WALL:

In this case - D, the frame consists of a beam as 8m which is supported by two columns as 4m each and bottom condition of columns are Hinged in the bases at the both ends and a beam is consider as shear connected beam with Shear wall which resist lateral loads and is not allowed for moment transfer to column directly and Only transferring shear force to column.

Frame consist external loads which are axial and lateral loads 100kN and 10kN respectively. Axial load act on frame which is on the mid span of the beam and lateral load act on the column top horizontal direction. In this case material are used as universal materials for beam and column.

Due to axial and lateral loads act on the frame, the frame tends to sway less with in permissible condition due to provide shear wall the end, the selection of material depends upon as per permissible defection.

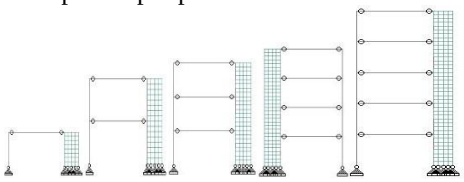

Fig 4: Hinged Base, Shear Connected Columns and Beams with Shear Wall Single bay system

11. SOFTWARE ANALYSIS:

Data : Case – B Pinned with bracing frame.

Introduction to Staad.pro V8i:

Stadd.Pro V8i is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modelling and design software products.

For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminium or timber buildings, transmission towers, stadiums or any other simple or complex structure, Stadd.Pro has been the choice of design professionals around the world for their specific analysis needs.

Stadd.Pro is a general purpose program for performing the analysis and design of a wide variety of types of structures.

The basic three activities which are to be carried out to achieve that goal.

- Model generation
- The calculations to obtain the analytical results
- Result verification - are all facilitated by tools contained in the program's graphical environment.

The staad model is prepared to the scale in the working space of staad. The frame structure model is generated which consists of beams and columns and then the material with their cross-section properties are inputted to staad. The loads are then assigned and after that the structure is analyzed with the help of the staad program.

The whole process of the analysis and design are given below.

Inputting the job Information:

Firstly, the information of the project is written after opening the staad. As the name of the project/job, Client's name and the date when project started and the name of the Engineer as well and much more information is inputted.

Generating the 3D or 2Dmodel geometry:

✓ Using the command file also called "The staad editor method".

✓ Using the graphical user interface (GUI).

We have done our whole of the programming with the help of GUI method because it is easier and much advance tool of staad. The model of the framed structure is generated in staad by Snap Node/Beam dialog box which appears when we select the grid from the top menu bar. Then the nodes and beams are created by this command at the suitable distances as per our need.

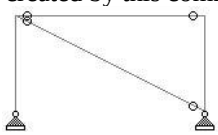

Fig 5: Generating model in to 2d frame

Assigning the material:
As after creating the beams and columns we will assign material to them as we require. Our design is concrete design hence we have assigned the concrete material to the beams and columns.
Specifying member properties:
The properties of the beams and columns is their size(width, depth of cross-section).So with the help of this command we have inputted the different properties (as circular, rectangular, square) and assign these properties to specified members.

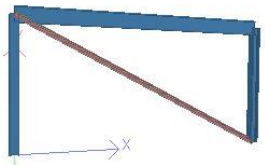

Fig 6: Rendering view model

Specifying material constants:
As we assigned the concrete material so by default we have the constants of concrete and we don't need to use this command separately. Or if we need to change the constants we can do so by this command.
Specifying Supports:
he supports are first created (as we created fixed supports) and then these are assigned to all the lowermost nodes of structure where we are going to design the foundation.

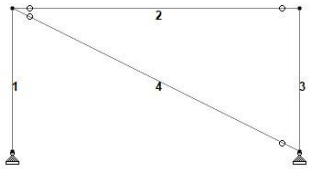

Fig 7: Assigning Support for column

Specifying Loads:
This is done in following two steps :

- ✓ Firstly creating all the load cases.
- ✓ Then assigning them to respective members and nodes.

The staad program can produce all types of loads and can assign them to the structure. It also has the capability to apply the dead load on the structure.

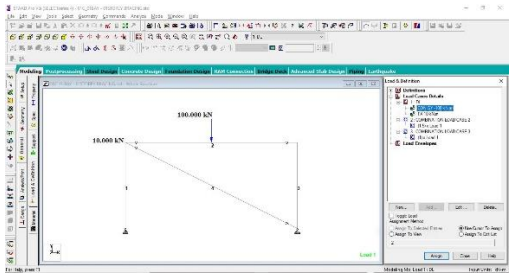

Fig 8: Applying loads on Beam And Column

Specifying the analysis type:
Before doing the analysis for the loads we require specifying analysis command which we need is linear static type. Choosing statics check, we will add this command.
Post-Analysis print command:
As we require obtaining member end forces and support reactions written in the output file. By clicking on post-analysis a dialog box will open then by clicking define command, we can add the commands which we need and can assign them to members for which these will be analyzed.
Run Analysis:
The structure will be analyzed to the loads and this command will also show if there is any warning or error.
Post-Processing mode:
We can see results in this mode. The deflection, bending moment, shear forces and reactions on supports can been on the structure with values. The figures shown below are under Dead Load. We can also see figures under Live Load or other which we want.

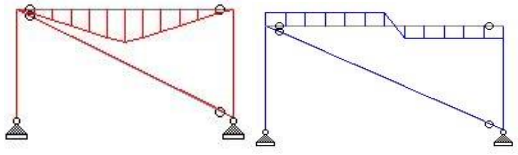

Fig 9: Bending moment and Shera force diagram

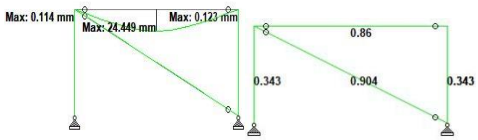

Fig 10: Deflection and Utilization ratio diagram

12. ANALYTICAL RESULT & DISCUSSION:

The analyses of both cases either Four cases systems using STAAD.pro software analysis to determine the behaviour, performance and section quantities of each cases.
Table shows comprehensible difference of quantities of section properties can be observed. Minimum displacements are found in Case – C and Case – D due to provision on of brace and shear wall. While analysing Case - A it is the maximum deflection and usage of steel section in (along X-direction) and (along Y-direction). Meanwhile, Table shows a clear prospect of steel take of no of cases and utilization ratio is obtained. The maximum no of steel quantities used in Case – A and minimum steel quantities optimized in Case - C and Case – D and while analysing Case – D here calculated along steel, if it calculates a shear wall in the case it is not economically. The below graph shows the steel quantities of different condition.

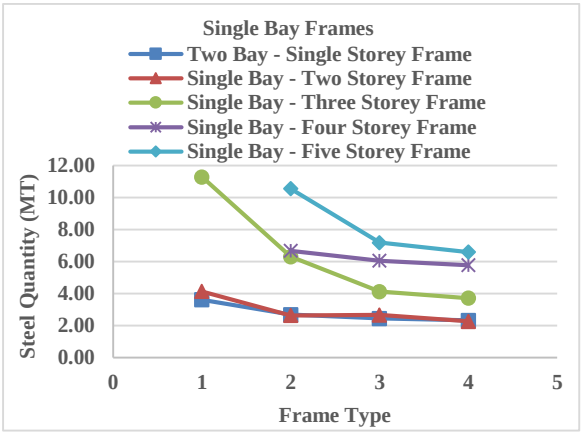

Fig 11: Steel Quantity Comparisons of Single bay Stories with Four cases

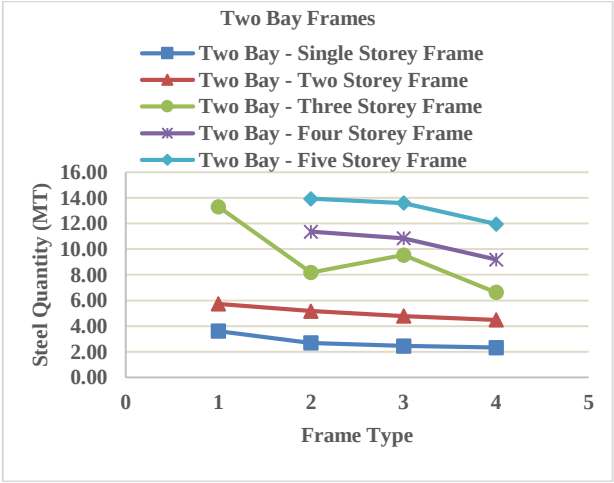

Fig 12: Steel Quantity Comparisons of Two bay Stories with Four cases

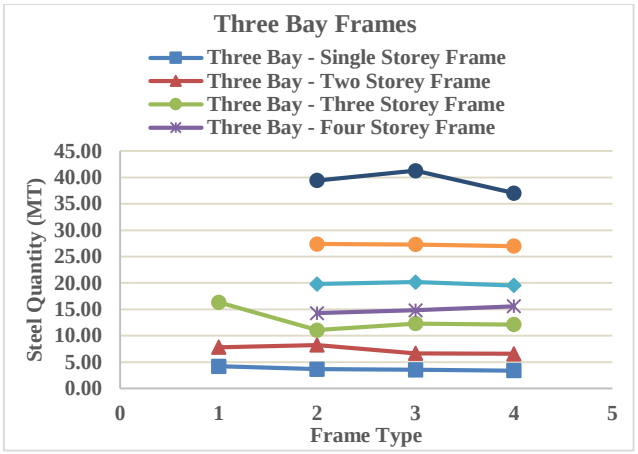

Fig 13: Steel Quantity Comparisons of Three bay Stories with Four cases

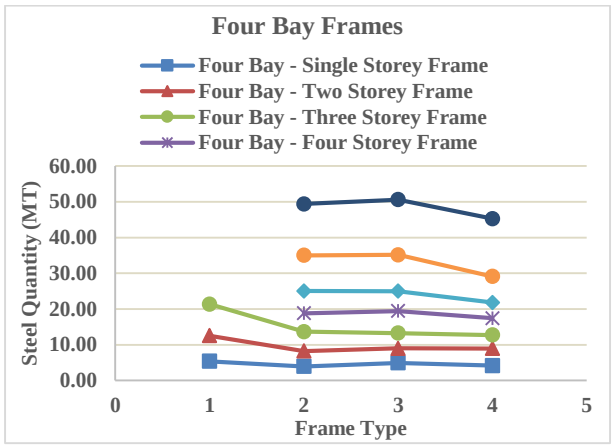

Fig 14: Steel Quantity Comparisons of Four bay Stories with Four cases

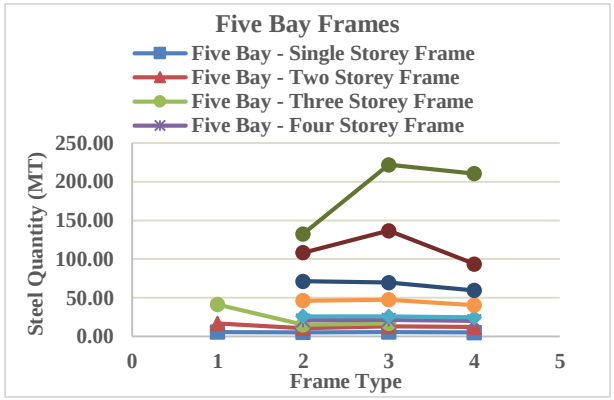

Fig 15: Steel Quantity Comparisons of Five bay Stories with Four cases

13. CONCLUSIONS:

The comparative studied on different steel structure systems has been modelled for its lateral resistance with different types of support conditions. From the obtained results, it can be concluded that 1. Fixed base and shear connected beam system case was showing more deflection and steel quantities to compare than other cases. 2. Hinged base and moment connected beam system was showing better performance in the system and compare to other cases which is showing better deflection and less quantity of steel properties. 3. When steel bracings are used in this case, it is seen that, there is almost the same percentage decrement in deflection and more quantity of steel properties to compare than case - B in both the loads. 4. Similarly when provide shear wall in the corner of frame which is doesn't allow maximum drift and less quantity of steel propertied but in the case demerit of additional cost of shear wall. For the proposed structure, choosing of a particular type of steel structure system also plays a vital role in the performance of a building subjected to lateral loads.

In structural engineering, it is important to understand lateral loads and their paths. These include frame types, diaphragms, and connections. Each project will have different project programs and requirements that will require the structural engineer to decide how to resist loads in the most economical way while meeting architectural and usage requirements and restraints.

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