Cost and Strength Optimization of ISMB and Hollow Section of Steel Structures

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Abstract - The use of steel framed structures for large industrial buildings permits the creation of buildings with large and uninterrupted span areas, with the advantage of low cost, light weight and easy installation. Portal frames have developed rapidly in recent years and are now widely applied to the construction of industrial factory buildings. In the increased price of materials, the civil engineers and the manufacturers are forced to reduce the costs of construction and shorten the implementation period to maintain their competitiveness. As a result, a new design trend was born the use of the analysis and design software to evaluate feasible design options, replacing the conventional design methods. In this work we use STAAD Pro V8i which is one of the most popular structural engineering software products for 3D model generation, analysis and multi-material design.

The main application of optimal analysis and design of steel structures is the size optimization, because this method is possible to minimize the weight of structures. While the strength and weight of a steel structure is a major component of the total cost, the minimization of the cost should be the final objective for optimum use of available resources. The total cost of a steel structure includes

(a) the material cost of structural members such as beams, columns, and bracings,

(b) the fabrication cost including the material costs of connection elements, bolts, and electrodes and the labour cost

(c) the cost of transporting the fabricated pieces to the construction field

(d) the erection cost including the material costs of connection elements, bolts, and electrodes and the labour cost.

In this work cost and strength optimizations is our major concern and encourage the use of the optimization approach in structural steel by practice and providing a more realistic way of model structural of steel and resulting in additional savings compared with the weight optimization problem.

The main factors influencing the cost and strength of a structure are delineated and their effects on various functions are discussed. Some criteria in optimization of a model are -

(i) Select commercially available sections with the lightest weight

(ii) Select the minimum number of different types of commercially available sections

(iii) While Optimizing section it is to be studied that what will the change in total weight of structure

(iv) While Optimizing section it is to be studied that what will the change in member forces of the structure, displacement and drift pattern in the different structure type.

Keywords - Cost; Optimization; Strength; Steel structure; STAAD Pro.

I INTRODUCTION

Steel is the most useful material for building structures with strength of approximately ten times that of concrete, steel is the ideal material for modern construction. Due to its large strength to weight ratio, steel structures tend to be more economical than concrete structures for tall buildings and large span buildings and bridges. Steel structures can be constructed very fast and this enables the structure to be used early thereby leading to overall economy. Steel structures are ductile and robust and can withstand severe loadings such as earthquakes. Steel structures can be easily repaired and retrofitted to carry higher loads. Steel is also a very eco-friendly material and steel structures can be easily dismantled and sold as scrap. Thus the lifecycle cost of steel structures, which includes the cost of construction, maintenance, repair and dismantling, can be less than that for concrete structures. Since steel is produced in the factory under better quality control, steel structures have higher reliability and safety.

The main objective of this thesis is to investigate the effectiveness of steel section, a multistory building steel frame structure (G+9) which is used as a commercial place. In this problem the different type of bracing system (ISMB section, HOLLOW section and combination) for different seismic zones (zone II, zone III, zone IV, zone V) and analyses the structure with STAAD Pro. Comparing the results for displacements, moments, drift, axial forces, and stresses, in between bare frame structure and structure with different type bracing systems & shear wall. And a comparative study is made to investigate the effective system among them.

Sumit Pahwa et al (2014) describes about an analytical comparative study on 1S2 transmission tower under wind and earthquake loads considering optimization technique. The optimization of wind and earthquake load is carried out by plotting graphs between earthquake forces with height, wind forces with height and tower with X and K bracing under wind and seismic load. All the calculation and analysis is carried out using STAAD PRO software and EXCEL spreadsheet.

A. Jesumi et al (2013) studied on the major system providing lateral load resistance in steel lattice towers is bracing system. There are different types of bracing systems for steel lattice towers. The heights of these towers vary from 20 to 500 meters, based on the practical requirements. This study has focused on identifying the economical bracing system for a given range of tower heights. Towers of height 40m and 50m have been analyzed with different types of bracing systems under wind loads.

Saleem M. Umair et al (2013) focused on the determining of optimum unbraced length of slender steel sections under bending and compression effects. Required objectives are achieved by selecting a wide range of steel sections having non compact to slender webs and flanges. After making a careful selection of different steel sections, each steel section is analyzed under compression and bending for a given unbraced length of steel member and optimum values of flange and web slenderness are determined. Same procedure is repeated for all selected steel sections for different unbraced length ratios. Results have determined the

optimum values of flange and web slenderness which can lead towards the minimum weight and cost of steel structures.

Vikash Khatri et al (2012) study is performed to compare the cost differences between bridge designs using conventional mild steel Fe 410 and high tensile steel Fe 590. Two cases of span supported and un-supported during construction are considered for comparison. Maximum flexural stresses, maximum deflection, weight and cost are compared for 40m span steel-concrete composite bridge for both the unsupported and supported conditions of the bridge span during construction. HPS steel is found to be most beneficial and economical in bridge design as compare to MS. Removing a girder line consistently reduced total system weight and improved overall design economy. Thus the 4-girders system is more economical then 5-girders system. However, the maximum deflection is found to increase more than two times the permissible deflection of L/600 for total dead and live load, for HPS steel in comparison to the mild steel girder case.

D. R. Panchal et al (2011) presents work, steel concrete composite, steel and R.C.C. options are considered for comparative study of G+30 storey commercial building which is situated in earthquake zone IV. Equivalent Static Method of Analysis is used. For modeling of Composite, Steel and R.C.C. structures, ETABS software is used and the results are compared; and it is found that composite structure is found to be more economical.

M.G.Kalyanshetti et al (2009) study is regarding the economy, load carrying capacity of all structural members and their corresponding safety measures. Economy is the main objective of this study involving comparison of conventional sectioned structures with tubular sectioned structure for given requirements. For study purpose superstructure-part of an industrial building is considered and comparison is made. Study reveals that, up to 40 to 50% saving in cost is achieved by using tubular sections.

İlyas Yildirim (2009) investigated optimal lateral bracing systems in steel structures under wind. For this purpose evolution strategies optimization method is used which is a member of the evolutionary algorithms search techniques. First optimum design of steel frames is introduced then evolution strategies technique is explained. This is followed by design loads and bracing systems and it is continued by the cost analysis of the models. Optimum designs of three different structures, comprising twelve different bracing models, are carried out. The calculations are carried out by a computer program (OPTSTEEL).

Ahmed B. Senouci (2009) presents a genetic algorithm model for the cost optimization of composite beams based on the load and resistance factor design (LRFD) specifications of the AISC. The model formulation includes the cost of concrete, steel beam, and shear studs. The results obtained show that the model is capable of achieving substantial cost savings. Hence, it can be of practical value to structural designers. A parametric study was also conducted to investigate the effects of beam spans and loadings on the cost optimization of composite beams.

II PROBLEM FORMULATION

In this work different structural steel sections are considered to find out most effective section to resist seismic forces and effectiveness also in their respective position in the structure.

The steel sections taken under consideration are –ISMB section and HOLLOW section are having variable thickness in a multi-storey building frame.

2.1 Geometry

The building has 4 bays in X direction and 4 bays in Z direction with the plan dimension 12m × 12 m and a storey height of 3 m each in all the floors and depth of foundation taken as 3 m. The building is kept symmetric in both orthogonal directions in plan to avoid torsional response under lateral force.

2.2 Modelling

The building is considered to be located in seismic zone II,III,IV and V and intended for residential use. The building is founded on medium strength soil through isolated footing under the columns. Response reduction factor for the special moment resisting frame has taken as 5.0 (assuming ductile detailing). The floor finish on the floors is taken to be 1.0 kN/m^2. The live load on floor is taken as 3.0 kN/m^{2}and that on the roof to be 1.5 kN/m^2. In seismic weight calculations, 25 % of the floor live loads are considered in the analysis.

Table 1: Details of Structure

S. No.	Description	Parameter
1	Depth of	3.0 m
2	Floor to Floor	3.0 m
3	Grade of	M-25
4	Type of steel	Fe-415
5	Column size	Depends on interpolation
6	Beam size	Depends on interpolation
7	Unit wt. of	20 KN/m3
8	Slab thickness	150 mm
9	Zone	II, III, IV,V
10	Live Load	4 KN/m2

III ANALYSIS OF VARIOUS MODELS

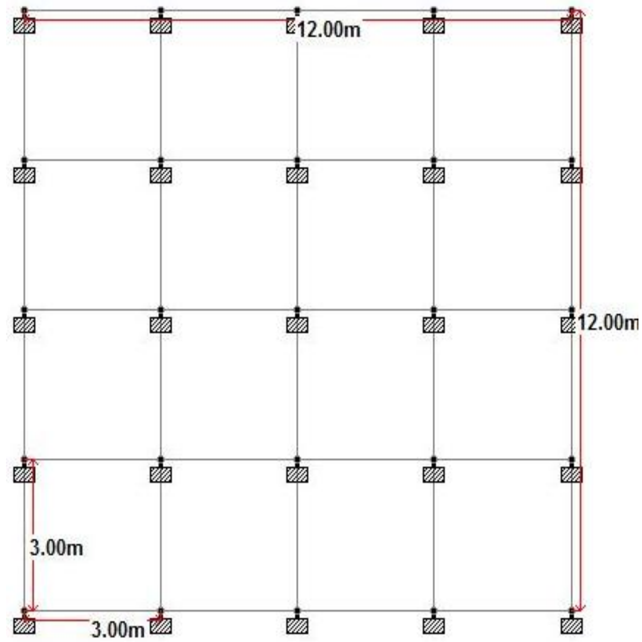

Fig. 1: Plan of the structure

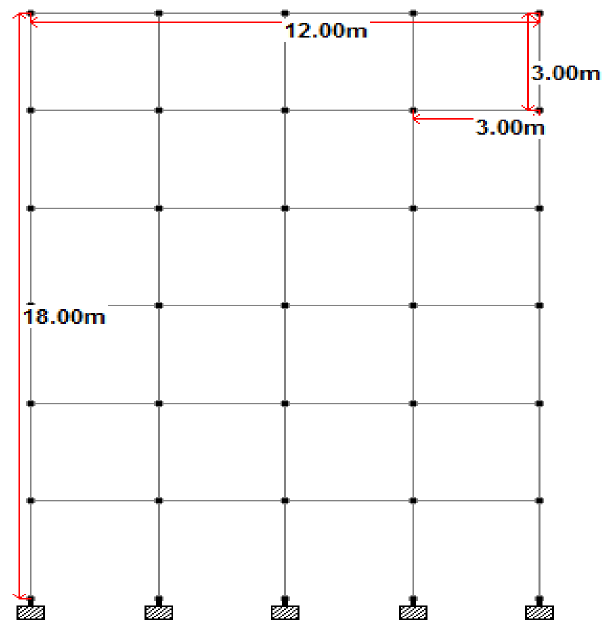

Fig. 2: Elevation of the structure

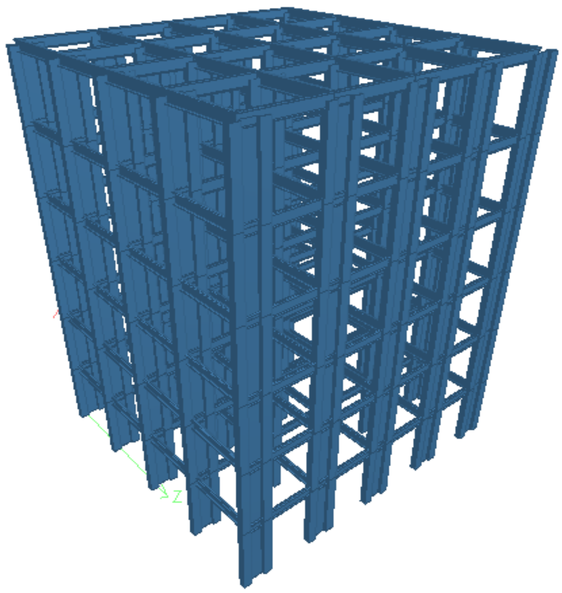

Fig.3 Isometric view of ISMB section

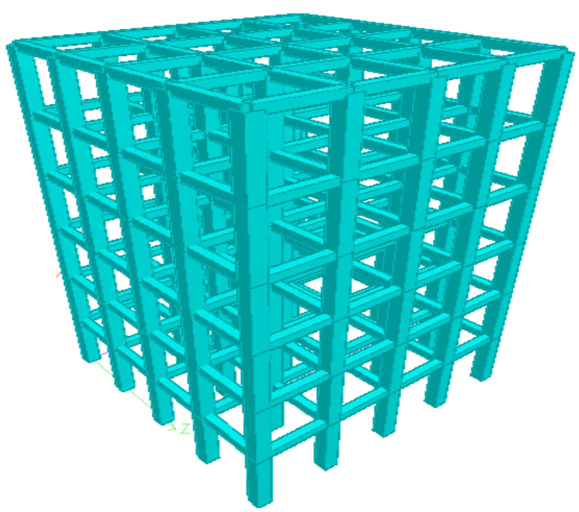

Fig.4 Isometric view of hollow section

IV RESULT ANALYSIS

Find the results for displacement, bending moment, axial forces etc and then compare the results to distinguish the effective section between provided different steel sections in different seismic zones.

Following sections presents the results obtained from these analyses.

1) CASE 1-ISMB framed steel structure

2) CASE 2-Hollow section framed steel structure

a. MAXIMUM LATERAL DISPLACEMENT

(a) It is observed that the displacement (X DIR) in top storey (maximum Displacement) is max in ISMB and minimum in HOLLOW section.

(b) It is observed that the displacement (Z DIR) in top storey (maximum Displacement) is max in ISMB and while providing HOLLOW section it is observed that displacement is greatly reduced in Hollow system compared ISMB sections.

Table 2: Maximum Displacements (mm) in X direction for structures in all seismic zones

X DIRECTION				
MAXIMUM DISPLACEMENT				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	9.69	15.49	23.23	34.83
HOLLOW SECTION	8.40	13.42	20.12	30.16

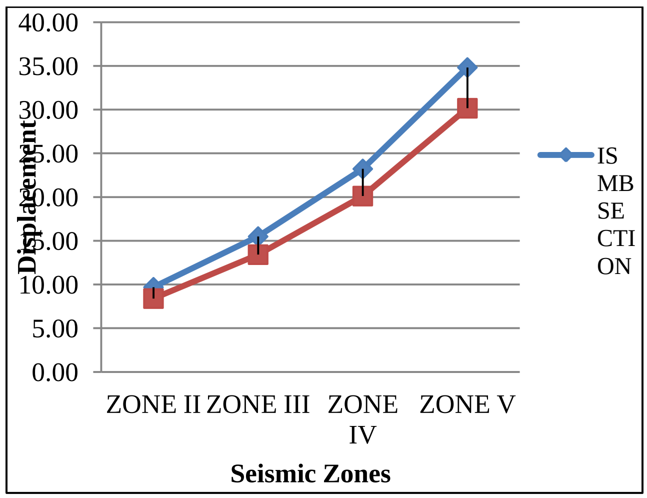

Fig. 5 Maximum Displacements (mm) in X Direction for all structures

Table 3: Maximum Displacements (mm) in X direction for structures in all seismic zones

Z DIRECTION				
TOP STORY DISPLACEMENT				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	24.57	39.29	58.92	88.37
HOLLOW SECTION	8.40	13.42	20.12	30.16

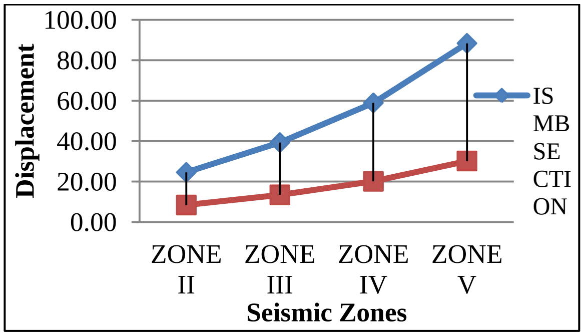

Fig. 6 Maximum Displacements (mm) in Z Direction for all structures

b. COLUMN FORCES

(a) Axial force in columns of the structure is maximum in ISMB section but when providing Hollow section it will reduced up to 11%

(b) Bending moment (M_y) it is studied that moment is reduced in HOLLOW section compared to ISMB section

(c) Bending moment (M_z) it is it is studied that moment is reduced in HOLLOW section compared to ISMB section

i. Axial Force

Table 4: Maximum axial forces in column of the structures

MAX. AXIAL FORCE - KN IN COLUMN				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	1675.95	1675.95	1835.27	2230.86
HOLLOW SECTION	1462.92	1462.92	1462.92	1737.60

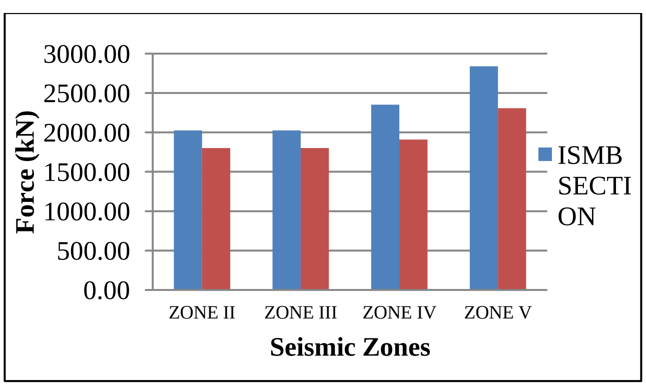

Fig. 7: Maximum axial forces in column of the structures

ii. Moments

(a) Moments in Y Direction

Table 5: Maximum moment (My) in column of the structures

MAX. moments in column My KN-m				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	230.42	368.43	552.44	828.46
HOLLOW SECTION	196.33	312.82	468.15	701.85

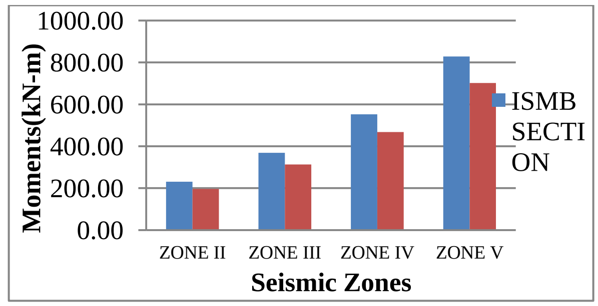

Fig. 8: Maximum moment (M_y) in column of the structure

(b) Moments in Z Direction

Table 6: Maximum moment (M_z) in column of the structures for all seismic zones

MAX. MOMENT Mz - kNm IN COLUMN				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	816.25	1300.75	1946.76	2915.76
HOLLOW SECTION	196.33	312.82	468.15	701.85

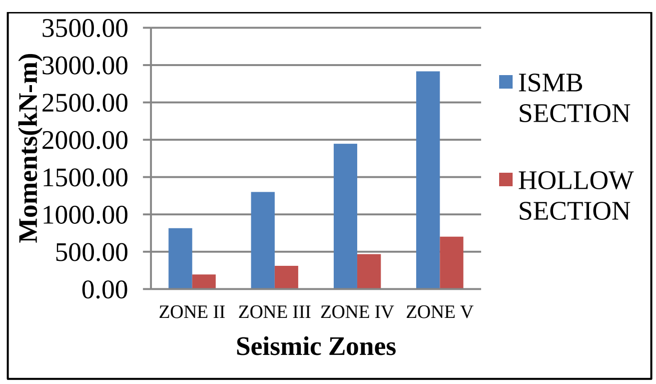

Fig.9: Maximum moment (M_z) in column of the structures

C. BEAM FORCES

(a) In beam maximum bending moment (Mz), it is observed that maximum is seen in ISMB section and minimum is seen in HOLLOW section.
(b) In shear force, it is observed that maximum is seen in ISMB section and minimum is seen in HOLLOW section.

i. Moments

Table 7: Maximum moment (Mz) in Beam members of the structures for all seismic zone

MAX. MOMENT Mz - kNm IN BEAM				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	202.79	304.94	441.14	645.44
HOLLOW SECTION	173.32	249.17	350.31	502.02

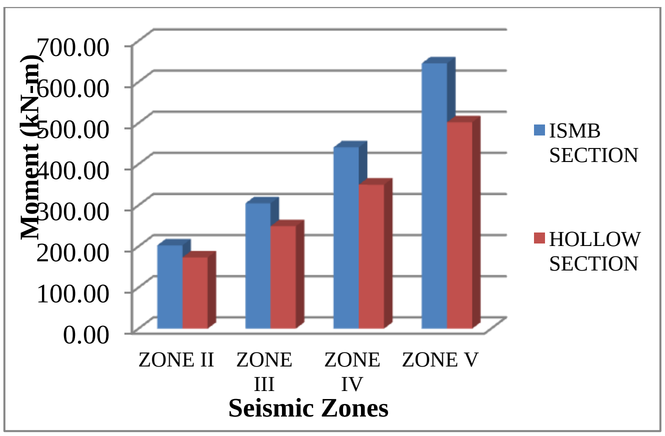

Fig. 10: Maximum moment (Mz) in Beam members of the structures Shear Force

ii. Shear force

Table 8: Maximum Shear Force in Beam members of the structures for all Seismic zones

MAX. SHEAR Y - kN IN BEAM				
TYPE	ZONE II	ZONE III	ZONE IV	ZONE V
ISMB SECTION	174.06	240.05	328.04	460.02
HOLLOW SECTION	157.43	206.88	272.81	496.34

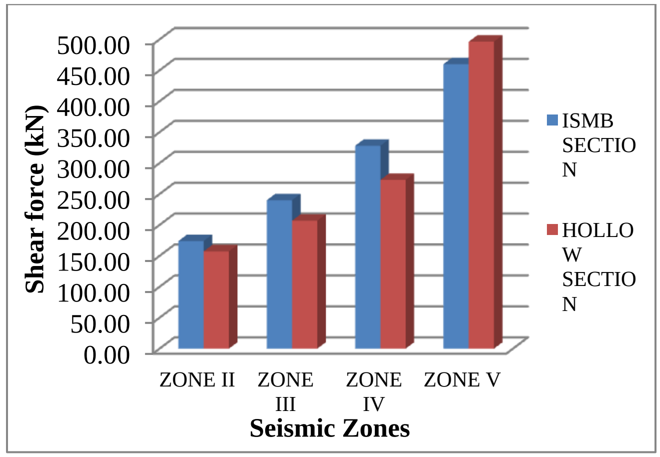

Fig. 11: Maximum shear force in Beam members of the structures

V CONCLUSIONS

After viewing and tabulating results and graphs it is observed and discussed here the effect of different type of structural system with structural steel, in multi-storey building in study the effect of earthquake forces. Here study has been carried out to find out the most economic and efficient system among the provided systems. The conclusions of the study are as under:-

1) To resist the forces coming/generated on the structure due to seismic activities it is found that HOLLOW section are quite efficient over other sections.
2) To control the deflection and displacement occurred on the structure due to earthquake forces it is observed that the structure having HOLLOW section as structural members are very much effective to control the displacements in comparison to ISMB section.
3) To achieve economy while designing the structure for seismic forces it is found that the structure having HOLLOW section is having minimum weight in compare to ISMB section.
4) For achieving overall economy and safety in designing & construction it is observed that in comparison to all above provided steel section; HOLLOW section is found most appropriate among all.

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