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Analysis and Design of an Irregular Steel Marine Structure

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Abstract: Due to requirement of unique architectural appearance of building, the regularity in plan, mass and stiffness may get disturbed and may lead to development of torsion in the structure. The two most significant aspects of new structures are form and function, which are growing more sophisticated as elements of equally sophisticated "systems" that we live in. Both the shape and the structural system must be sound in order for the construction to be both aesthetically pleasing and functionally successful. Nowadays, it is usual to see structures that are irregularly shaped or sculptural in nature. The irregular shape building differs from regular building in terms of shape, structure, reliability, economy and aesthetic appearance. The study focuses on design and load analysis of an irregular steel structure which is in the shape of a ship. The design and analysis is performed in STAAD PRO software.
Keywords: Bracing, Storey Drift, Irregular building, Stiffness, Torsion, Staad pro etc.

I. INTRODUCTION

A. Irregular Structures

Irregular structures, like structures having different shaped plans, that can be defined "irregular" according to both perceptive criteria and irregularity rules provided by guidelines, show that, if the diaphragms are rigid and the columns are distributed according to the shape, the irregularity is "apparent". The disturbance to the response, induced by the irregularity consists of torsional effects, that can be accounted for, at design stage. Regularity of the structure deals with the a symmetrical and compact shape of the structure. The importance of regularity of the building is for avoiding unpredictable stress concentration that can cause local collapses and modification of the dynamic behavior.

1) Stiffness irregularity; it is nothing but soft storey in this stiffness of the member in the frame are not equal and they vary according to floor height. Soft storey in which the lateral stiffness is less than 70percent of the storey above or less than 80% of the average lateral stiffness of the storey above. extreme soft storey –an extreme soft storey is one in which the lateral stiffness is less than the 60% of the storey above or less than 70% of the average stiffness of the three storey above.
2) Mass irregularity; mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200% of that of its adjacent stories. In case of roof irregularity need not to be considered.
3) Vertical geometric irregularity; the structure is considered to be geometrical irregular when horizontal dimension of lateral force resisting system in any storey is more than 150 % of that in its adjacent storey.
4) In plan discontinuity in vertical element resisting lateral force: an in plan offset of lateral force resisting element greater than the length of those element.
5) Discontinuity in capacity: weak storey, weak storey is one in which storey lateral strength is less than is 80% of that in storey above.

B. Torsion In Structures

Due to dynamic loads such as earthquake load or wind load the high rise structure subjected to unbalanced couple and it rotate about the axis of center of stiffness of building this phenomenon is known as torsion in building. These effects occur due to different reasons, such as no uniform distribution of the mass, stiffness and strength, torsional components of the ground movement, etc. In ductile structures, the main consequence of floor twist is an unequal demand of lateral displacements in the elements of the structure. Design codes incorporate especial requirements to take into account the torsional effects, which usually imply de-amplification of eccentricity and the consideration of an accidental eccentricity. The seismic response of buildings subjected to ground motions may be significantly modified due to the occurrence of torsional effects. As a result, the floors of the building not only translate laterally but also rotate along a vertical axis. Centre of mass is a position defined relative to an object or system of objects.

It is the average position of all the parts of the system, weighted according to their masses. For simple rigid objects with uniform density, the center of mass is located at the centroid. Centre of rigidity is the where the entire stiffness of the building acts. Stiffness is contributed by the column and shear walls of the building

The majority of the structures are constructed in plain rectangular designs. Uneven structures combined with odd and odd shapes, on the other hand, are frequently destined to become iconic. When compared to traditional buildings, these irregularly shaped structures usually give off a very futuristic look. Such structures quickly stand out as architectural icons, often relating directly to the stakeholders' distinct personality and ideology. These irregularly shaped building designs now rely on digital technologies for their design and construction.

II. LITERATURE REVIEW

A. Design Of An Irregular Structure

Francisco crisafulli , Agustín reboredo and Gonzalo torrisi (2004), reduced the ductility capacity of the system, in order to account for the torsional strength of the structure and the yield displacement of the elements in order to yield simultaneously. Both stiffness and strength eccentricity affect the torsional behavior of the systems, although the latter has a more significant influence during the ductile response of the structure. The maximum floor rotation and lateral displacement of the centre of mass do not occur simultaneously and, therefore, the ductility demand on the elements does not necessarily increase when the twist also increases.

Kevadkar m. D., kodag p. B (2013) Has done lateral load analysis of R.C.C. Building (G+12) by considering 3 models. The first model was without bracing and shear wall, second model with different shear wall system and third model with different bracing system. The computer aided analysis was done by using E-TABS to find out the effective lateral load resisting system during earthquake in high seismic areas. The performance of the building was evaluated in terms of Lateral Displacement, Storey Shear and Storey Drifts, Base shear and Demand Capacity.

Shaik Muneer Hussain, Dr. Sunil Kumar Tengli (2018) They understood the torsional behavior of asymmetric buildings by modeling and analyzing a 14 storey buildings using three dimensional dynamic analysis (Response Spectrum Method) procedure with ETABS as per the IS Code 1893:2002 (part 1). Studied the effects and behavioral patterns of irregular multi-storied buildings against different forces acting on it during the earthquakes. Concluded that the results show that there is an increase in shear forces in columns especially in irregular structure due to torsion. Special moment resisting frame is more suitable in severe seismic zones than ordinary moment resisting frame.

Prof. S .Vijaya Bhaskar Reddy and V.Madhu (2018) Studied detailed analysis on simulation tools ETABS and STAAD PRO, which have been used for analysis and design of rectangular Plan with vertical regular and rectangular Plan with Vertical geometrically irregular multi-storey building. Results of max vertical reactions of a 12-storey regular building. As per table 5.1 it has been concluded that the max reaction produced is 4572.12kN in ETABS and 4624.92kN in STAAD Pro. Maximum displacement is along x- direction and its value is 106.25mm (in STAAD Pro.) for irregular building and 53.47mm (in ETABS) along z direction for regular building. It has been concluded that the ETABS gave lesser area of steel required as compared to STAAD Pro. Concluded that in case of beam whereas in case of column steel calculated is same by both software's.

Srishti Bhomaj, Parikshit Ghodake, J.P.Patankar K. (2019) Have calculated The Center of mass, center of stiffness, torsion and base shear developed for comparison between the regular and irregular buildings. Due to dynamic loads such as earthquake load or wind load the high rise structure subjected to unbalanced couple and it rotate about the axis of center of stiffness of building this phenomenon is known as torsion in building. They concluded that Centre of mass and center of stiffness coincides in regular building whereas in irregular building some eccentricity is observed. Torsion was developed in irregular building due to earthquake along the X┐ direction. In regular building no torsion was observed in columns whereas in irregular building every column was subjected to torsion. Found out that, the sectional requirements of an irregular building are relatively higher than that of regular buildings. Shruti Bharvase, Priyanka Patil (2019) Studied Analysis of vertically regular steel structures and irregular steel structures having irregularities such as mass, stiffness and set back irregularity in ETABSv2016 software. After the testing they realized that maximum displacement is observed at top storey for wind load case acting in y direction. It can be suggested that the weak storey effect and the mass irregularity effect can be efficient to some extent as the results obtained are similar to that of regular building. The maximum destruction can be observed due to the soft storey effect. The use of bracing system can be done to reduce such destructions.

Mayuri Awale, Shanila Qureshi, Oais Patel, Muzammil Ahmad Ansari, Sumedh Atrahe, Usman Ghani, Prof. Mohd Azaz (2021) focuses on the design and load analysis of an irregular A shaped (G+3) multi-storey mall. Their objective was to minimize the unpredictably high stress concentrations that may cause local collapses and change in dynamic behavior.

They used software's like AUTOCAD and STAAD for designing and load analysis of the structure. After modeling the structure they got the maximum value of story drift in Y-direction at 1st floor.

B. Bracing Systems

Poncet ,L.And Trembly(2004) he used the equivalent static load method and response spectrums analysis method for the analysis of eight storey building and considering the effect of mass irregularity and impact of braced steel frames structure with different setback configration and find response spectrum give the more accurate result.

Amini Moein a., M. Hosseini (2012) Studied the effect of bracing arrangement in the seismic behavior of buildings with various concentric bracings by nonlinear static and dynamic analysis. In his study a set of regular multi-story steel buildings were considered with three kinds of x, v and chevron bracing, in two placements of 'two adjacent bays' and 'two non-adjacent bays' along the building height. Results show that in all cases, bracing arrangement in non-adjacent bays leads to lower stiffness but higher strength than in adjacent bays.

Jagadish J. S , Tejas D. Doshi (2013) tried to show the effect of different types of bracing systems in G+15 storey steel building. They used Single-Diagonal, X bracing, Double X bracing, K bracing, V bracing. They used STAAD PRO for computing different parameters of analysis of steel building. They used ISA200x200x12thk bracing. In conclusion they found that, bracings are good to reduce the displacement and in case of K and V-bracing, the displacement is higher than without bracing because of irregularity in shape of the structure.

S. K. Karthik Reddy, Sai Kala Kondepudi, Harsha Kaviti (2015) Studied that a comparative study on behavior of multi storied building with different types and arrangement of bracing system. They studied a (G+15) regular shaped multi storied building with using wind speed of 62m/s and seismic load applied on it for zone II by using equivalent static analysis. In this study they concluded that X-bracing is more effective as it reduces the nodal deflection by 80%. Also V and inverted V bracing do not show much different in increase of weight and base shear of structure.

Praveena G.M., Thejaswini R.M. (2015) Studied the commonly used bracing systems for high rise steel structure and to summarize the typical best type of bracing system for tall structures. Equivalent static analysis Method and Wind load analysis method was used to analysis the structure. Resulted as, X type bracing has the has the maximum reduction if drift percentage compared to unbraced model and Inverted V-bracing has minimum drift per unit quantity of steel compared to other bracing types.

Dhruba jyoti Borthakur , Dr. (Mrs) Nayanmoni Chetia (2016) Studied the effect of reduction in responses of a structure under lateral loading due to the incorporation of a bracing system. Due to the effect of eccentric loading a building normally experiences lateral as well as torsional displacement under seismic loading. After analyzing the models with bracing and without bracing on shake table the following results were concluded. It was observed that lateral movement decreases up to 80% due to the incorporation of the bracing system. Likewise, reduction in velocity and acceleration is also noted. Bracing system also results in reduction of torsional movement of the structure up to a greater extent.

Amol S. Rajas (2016) Analyzed high rise regular type of buildings (G+19) with difference bracing system under the influence of wind load. They studied X, V, diagonal and chevron bracing at different locations by using STAAD Pro V8i for shear force and bending moment parameters. As per IS 456-2000 for reinforced concrete design and IS 800- 2007 for steel design of bracing elements. They assumed the wind speed 44 m/s. They concluded that chevron bracing proves to be most effective among other bracing systems in reduction of bending moment by 34.2% in y direction and 37.7% in z direction and also mentioned that provision of bracing system can be effectively improve the performance of the structure with negligible increase dead load on the structure.

J.P.Sweetlin, R.Saranraj, P.Vijayakumar(2016) Studied comparison of displacement for regular and irregular building for the zone 2 .They analyses the G+10 building for the analysis purpose by using the STAAD-PRO software. They consider only the geometric irregular building with different set back. And conclude that the displacement have direct co relation with mass of building so displacement in regular building g is more than irregular building and story drift is also more in regular building. Because they consider only the geometric irregular building.

Kamran Karsaz , Seyed Vahid Razavi Tosee (2018) Studied 3, 5, 10 and 15 storey steel buildings with moment resisting frames with five different bracing systems. To compare the bracing systems and to know which of these systems had a better effect on the structure performance, response-based damage model in which is based on stiffness, was used. The structures subjected to five earthquakes and then their results were analyzed by conducting pushover analysis. Based on the results of pushover analysis, it was found out that among studied bracing systems, the X┐ bracing system had the lowest ductility with lower value of behavior factor, but its initial stiffness and yield stress were higher than that of other study systems.

K. Anitha, M. Santhiya (2018) Comparatively studied the different framing system for multi storey composite buildings (G+10) with the introduction of irregular geometry. They analyzed the above mentioned structure subjected to basic winds speed of 50 m/s and zone III seismic activity with the help of ETAB software. They stated that double diagonal bracing system i.e. X bracing provides minimum increase in load for steel bracing as compared to K, V etc. types of eccentric bracing arrangements. Also, they concluded that double diagonal (concentric) bracing system reduces the storey drift more effectively.

C. Seismic Analysis

E. Hassaballa, Fathelrahman M. Adam., M. A. Ismaeil (2013) Investigated the performance of existing buildings if exposed to seismic loads. The frame was analyzed using the response spectrum method to calculate the seismic displacements and stresses. The results obtained, clearly, show that the nodal displacements caused drifts in excess of approximately 2 to 3 times the allowable drifts. The horizontal motion has a greater effect on the axial compression loads of the exterior columns compared to the interior columns and the compressive stresses in ground floor columns were about 1.2 to 2 times the tensile stresses. The maximum values of compressive and tensile stresses in beams are approximately equal. Resulted in Bending moments in beams and columns due to seismic excitation showed much larger values compared to that due to static loads.

Mr. S.Mahesh , Mr. Dr.B.Panduranga Rao (2014) Studied G+11 multi story building is studied for earth quake and wind load using ETABS and STAAS PRO V8i. The behavior of G+11 multistory building of regular and irregular configuration under earth quake is complex and it varies of wind loads are assumed to act simultaneously with earth quake loads. These analysis are carried out by considering different seismic zones and for each zone the behavior is assessed by taking three different types of soils namely Hard , Medium and Soft. Different response like story drift, displacements base shear are plotted for different zones and different types of soils. When compared the both the regular and irregular configuration, story drift and the base shear value is more in the regular configuration. Because of the structure have more symmetrical dimensions.

Ashvin soni (2015) presented a paper on effect of irregularities in building and their consequence. She use the response spectrum method for the analysis of G+10 building .She consider the 5 frames to make the building irregular in 1 frame consider regular building in second floor consider swimming pool on top storey in third frame consider heavy loading at 4th and 7th floor in fourth frame consider 1st and 2nd floor have a soft storey and in last 5th frame consider 4th and 5th storey is soft storey and find the result in form of storey drift and displacement. So she observed that frame 2 and frame 5 was weakest it suffer maximum displacement and frame 1 suffer least displacement. And storey drift is maximum in frame 3 which change abruptly and frame 4 and frame 5 also give max storey drift for bottom two storey and middle storey.

Chia-Hung Fang and Roberto T. Leon,(2018) Studied The horizontal torsional and vertical irregularities for symmetric and asymmetric braced frame structures by conducting nonlinear static and time history analyses on a small set of four-story frames. The torsional behavior of braced frames can be significantly influenced by the sequence of brace buckling, hinge development in beams or columns, and in-plane deformation of the diaphragm, even for the case of symmetric configurations. The ultimate strength of the structures with rigid diaphragm constraints is higher than the ultimate strength of those with semi rigid diaphragms. The inclusion of infinite in-plane diaphragm stiffness leads to higher global strengths of structure because of the robust in-plane force redistribution mechanism. T. Jayakrishna, K. Murali, Powar Satish, J Seetunya. (2018) Compared the results of seismic analysis of regular and irregular building multi-storey building by considering different seismic zones. A different response for displacements of base shear, storey drift is plotted for different zones for different types of soils. The whole design was carried out in STAAD Pro software which covers all aspects of structural engineering. Compared to vertical irregular model lateral displacement is less in regular model. Almost the base shear is same in regular and irregular models, max base shear in zone 5 in regular is 1372.3 KN and in irregular 1349.5 KN. Compare to irregular model the regular model shows less displacement with a max displacement of 55.16mm in zone 5.

D. Tubular Sections

M.G. Kalyanshetti, G.S. Mirajkar (2012) Analysed 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. Revealed that, up to 40 to 50% saving in cost is achieved by using tubular sections.

V.Rajendra kumar, Ranga rao V.(2017) Compared the regular and irregular structure using Staad pro and using method of analysis are response spectrum and time history and observe the result for structure in various zone .result is obtained in form of displacement and base shear at various level analysis is done for G+10 building it is observed that the zone 3, zone 4, zone 5 having 37%,58%,and 72% more base shear than zone 2.and lateral displacement is maximum in zo ne 5 and minimum in zone 2.

Hassballa A.E. et al.(2018) he analyses the multistory building by response spectrum method. by using STAAD PRO SOFTWARE studied the seismic analysis of RC building and investigate the performance of existing building if exposed to seismic loads. .They considers the static load and seismic load for the analysis of multistoried building and result was obtained from this study is that for the large displacement response spectrum require a large dimension for seismic analysis. And conclude that drift is obtained from this analysis is about 2 to 3 times the allowable drift. Resulting from large displacement due to combination of static load and seismic load.

Rakesh Kumar Gupta , Prof. D. L. Budhlani (2018) Present a paper on plan irregularity of different type he used a G+10 building for the seismic analysis by considering the seismic load live and dead load using the STAAD PRO software by using the response spectrum method as per is 1893 :2016 and 1893:2002. All combinations are considered as per IS 1893-(part I). Result is obtained from this study is such that seismic analysis as per guidelines of IS 1893:2016 shows higher value of base shear than as per IS 1893:2002. Also maximum lateral displacement in horizontal directions shows large value by response spectrum method as pe IS1893-2016

Sourabh Dhiman, Nirbhay Thakur, Nitish Kumar Sharma (2019) Analyzed behavior of columns of steel framed structure with various steel sections from various reviewed paper. From review various studies it concluded that tubular sections turns out to be efficient. Results obtained was, Tubular sections prove to be economical as they save almost 50 % to 60 % cost. Derive overall economy. The consumption of steel of whole industrial building can be reduced by deciding appropriate geometry of truss and by using hollow steel section with compare to conventional steel section.

Saurabh R. More, Dr. Atul B. Pujari. (2022) In this study, analysis and design of 13 story industrial steel structure with conventional sections and tubular sections is done. They did Comparison of analysis results on the basis of base shear, top story displacement, weight of structure. Tube frame construction was first used in the DeWitt-Chestnut Apartment Building, designed by fahzul Rahman Khan in 1963, Chicago. From the modular investigation it can be inferred that, steel tube structures are more adaptable than regular conventional steel structure. The tubular system is effective to resist the overall displacement than conventional system. Revealed that tubular sections prove to be economical. Total saving of almost 12–15 % in cost is achieved.

III. CONCLUSION

It has been found that any Irregular structure is cumbersome to design and also to analyze its loading. Displacement, Increase in base shear due to Torsion, Seismic Response, Story drift, etc. are the Critical factors leading to major damage of structure therefore, it is essential to analyze irregular structure carefully for these governing factors.

By using Steel bracings, Tubular sections, etc. damages can be reduced up to great extent and with the help of latest software's we can achieve the architectural aesthetics with the required structural stability.

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