

# A REVIEW PAPER ON ANALYTICAL STUDY ON THE STRUCTURE BEHAVIOUR OF REGULAR AND IRREGULAR SPACE FRAME BY STAAD.PRO V8i

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**ABSTRACT:** A procedure of optimizing a space truss only by varying the geometric shape of the truss and keeping the cross section of the element kept constant. The shape variations will be done on the basis of raising the height. The maximum deflection produced in the structure, weight of steel required by the structure and percentage of failed member has been considered as measured. Optimization is a process of subjecting all members present in the structure to minimum usage thereby ensuring the utilization ratio of each and every element more than 80%. It is to be noted that the structural properties not be compromised. The structure has to be made of limit state design and should be simply supported roof. Space truss design in the technique for assigning a structure using skeleton-type approach, as opposed to traditional piece-by-piece or ground-up construction. Irrespective of advantage of the structure economical efficiently of structure decides success of it. Hence the space truss will be designed and optimized during our project. The shape will be varied for the best result and optimized shape is to be determined.

**KEYWORDS:** *Symmetric And asymmetric Structure, Building Analysis, Storey Displacement, Base Shear, Storey Drift, STAAD-Pro v8i*

## I. INTRODUCTION

The growing interest in space frame structure has a witnessed worldwide over a last half century. It forms to accommodate large unobstructed area and satisfy the requirement for lightness economy and speedy construction. New and imaginative application of space frame are being demonstrated in the total range of building types such as sport arenas, exhibition pavilions assembly halls transportation terminals, airplane hangars, workshops warehouse. They have been used not only on long span roofs but also on mid and short span enclosure as roofs, floors exterior wall and canopies. But the space frame highly statically indeterminate and their analysis lead to extremely tedious computation if done by hand. The difficulty of complicated analysis as such system has contributed his limited use. But by using computer program it possible to analysis very complex space structure with greater accuracy and less time involved. A space frame or space structure is a truss like, lightweight rigid structure constructed from interlocking struts in a geometric pattern. Space frame can be used to span large areas with few interior supports. In practice the rigid jointed frames such as building frames are usually three-dimensional space structure. However, for simplicity in design, the space structure is considered as a number of independent plane frames interact with one another leading to a redistribution of internal forces and the development of torsional moments in the members of the space frame. Although the neglect of the torsional moments results in considerable simplification, it is neither economical nor safe in all cases. A grid structure is another example in which the neglect of twisting moment is neither safe nor economical. In dealing with rigid jointed space frames, the rotational coordinates corresponding to rotations about three Cartesian axes and couples about them will be represented by double headed arrows in accordance with the vector notation and the right-handed screw system. Although the members of a grid structure generally lie in one plane, the twisting moments are present because the external loads are normal to the plane of the grid. In a very broad sense, the definition of the space frame is literally a three-dimensional structure. However, in a more restricted sense, space frame means some type of special structure action in three dimensions. Sometimes structural engineers and architects seem to fail to convey with it what they really want to communicate.

## II. LITERATURE REVIEW

Manmohan Singh Thakur<sup>1</sup>, Dr.Suman Sharma (2017) Objective of this research to study vibration of two different types of frame one is square and other is tubular frame. In this work we will go to compared natural frequency of vibration between a tubular and square frame and trying to take some conclusion. In this analysis we will obtain vibration behaviour of motorcycle frame with different cross-section. In this research we took two materials one is aluminium and other is steel.

Disha Sahadevan<sup>1</sup>, MeghaVijayan (2017) describes the maximum displacement, storey drift and stiffness are analysed in regular and irregular building with square columns, circular column and with specially shaped columns. The maximum displacement is decreased for G+9 stories ranges is from 20% to 30%. The storey drift is decreased by 20% - 40% in Z shaped column while comparing with the equivalent square, circle column in G+9 stories. The stiffness is increased by 60% in Z shaped column while comparing with the equivalent square, circle column in G+9 stories. The specially shaped Z column achieves these categories.

Anuja Dhattrak<sup>1</sup>, Dr. R. S. Talikoti (2016) ,In this project a steel building model is taken, this model is compared in different aspects such as Natural frequencies, fundamental time period, inter story drift and base shear etc. using different bracing configuration in different locations. After the numbers of trial, the results of seismic analysis of high rise steel building with different pattern of bracing system which type of bracing at which location is more suitable would be selected for the structure.

Sashi Kumar Kunnath (2016) ,A threat-independent approach or the alternate path method forms the basis of the simulations wherein the extreme event is modelled via column removal scenarios. Using a prototype RC frame building, issues and considerations in constitutive modelling of materials, options in modelling the structural elements and specification of gravity loads are discussed with the goal of achieving consistent models that can be used in collapse scenarios involving successive loss of load-bearing columns at the lowest level of the building. The role of the floor slabs in mobilizing centenary action and influencing the progressive collapse response is also highlighted. Finally, an energy-based approach for identifying the proximity to collapse of regular multi-story buildings is proposed.

K.Selvam, R.Divyameena (2016) ,This project deals with the optimization of steel space truss. Optimization is a process of subjecting all members present in the structure to minimum usage thereby ensuring the utilization ratio of each and every element more than 80%. It is to be noted that the structural properties not be compromised. The structure has to be made of limit state design and should be simply supported roof. Space truss design is the technique for assigning a structure using skeleton-type approach, as opposed to traditional piece-by-piece or ground-up construction. Irrespective of advantage of the structure, economical efficiency of structure decides success of it. Hence the space truss was designed and optimized during our project. The shapes were varied for the best result and optimized shape was achieved. From this optimized shape trials were carried out with different depths and finally concluded the best.

Aniket N Tolani, Aniket S. Patil, Ganesh N. Patil, Vedang H. Vadalkar, (2016), These structures exhibit non-linear behaviour, as opposed to linear relationships observed in conventional structures, which use steel as its primary material resource. The non-linear relationship can be observed in geometry as well as in material aspects. These have been presented in the first part of this paper. The second part focuses on comparison of tensile structures over space frames structures which are generally used for covering areas. The area selected for the stated purpose is an entrance canopy. Computer aids like Staad. Pro and Form Finder are used. The end conclusion, which the study aims to show, is that the tensile membrane structure could outmatch the conventional systems in terms of construction difficulties, economic liabilities and resource/material requirement.

SARIKAB.SHINDE, M.SHIMPALE (2015) aim of this paper is to the study double layer barrel vault (DLBV) of 3D truss type. Barrel vault are popular way of spanning large areas with few intermediate supports Truss type double layer barrel vault is simple structural formation made up of network of longitudinal, transverse and braced member with curvature in one direction only. Truss type barrel vault are analysed and designed for different load such as live load, wind load and the combination of loads. The truss type barrel vault is designed as per IS: 800-2007 and analysis performed by using STAAD. Pro 2007. This work leads to the comparison on span, maximum deflection, self-weight and cost criterions

Prakarsh A. Sangave, Shubhangi M. Nikate (2015), In this project optimization was carried out on whole building frame not on an individual element. The fundamental optimization criterion chosen is the area of reinforcement per square feet. Analysis and design results are presented in the form of required area of reinforcement per square feet in (mm<sup>2</sup>) in optimization techniques for overall structure. The result shows that, after application of different optimization methodologies, a significant saving in cost of material and there by the cost of construction can be done.

M. Overend , and G.A.R. Parke (2015) ,However, to date there is still no agreement on a definite mathematical model that accurately predicts the failure of glass, hence resulting in disjointed and sometimes conflicting design data for this brittle unforgiving material. This induces engineers to adopt large factors of safety and devise inefficient glass structures. A design

methodology is therefore advanced to determine the strength of annealed and tempered glass panels. This paper provides an overview of this method and gives examples of its application.

Dhananjay.S.Pawar, S.Abdulla, U. Phadnis, Ravi.G.maske, Raju .S.Shinde<sup>4</sup> (2015) The horizontal movement is the most specific feature of earthquake action because of its strength and because structures are generally better designed to resist gravity than horizontal forces. These forces produce large stresses, strains, deformation and displacement particularly in tall structures. To keep displacement within limit generally bracing is provided in steel structure. Bracings are generally used to increase lateral-stiffness, lateral- strength as well as lateral stability of the frame. Variations in the column stiffness can influence the mode of failure and lateral stiffness of the bracing. In this study steel frame is modelled and analysed three Parts viz., (i) Model without Steel bracing (bare frame), (ii) Model completely with fully braced steel frame („Cross“ bracing), (iii) Model completely with fully braced steel frame („Single diagonal“ bracing).

Amit Kumar, Anant Kumar, Shyam Kishor Kumar, Krishna Murari (2014) , The seismic inertia forces generated at its floor levels are transferred through the various beams and columns to the ground. The failure of a column can affect the stability of the whole building, but the failure of a beam causes localized effect. Therefore, it is better to make beams to be the ductile weak links than columns. This method of designing RC buildings is called the strong-column weak-beam design method. If the frame is designed on the basis of strong column-weak beam concept the possibilities of collapse due to sway mechanisms can be completely eliminated. In multi storey frame this can be achieved by allowing the plastic hinges to form, in a predetermined sequence only at the ends of all the beams while the columns remain essentially in elastic stage and by avoiding shear mode of failures in columns and beams. This procedure for design is known as Capacity based design which would be the future design philosophy for earthquake resistant design of multi storey reinforced concrete frames.

Pei-Shan Chen (2014) describes the Space Frame, which is invented by the author, is a bar-linked structure configured with one-layer of chords and diagonal members [1,2]. Unlike a conventional double layer space frame, the 1.5-Layer Space Frame has no lower chords, or when it is oriented upside down, no upper chords. And unlike a single layer space frame, diagonal members are mounted onto the latticed surface and efficiently strengthen it so that the entire structure can be constructed in subtle curvatures or as a plane. The present paper introduces the geometrical features of the 1.5-Layer Space Frame and presents more configuration patterns to construct variations of the 1.5-Layer Space Frames in planar and curved forms.

AnshulSud, Raghav Singh Shekhawat, PoonamDhima (2014) describes the most basic lateral load resisting elements in an earthquake resistant building. To avoid torsion in buildings, shear walls must be placed symmetrically in plan. In this paper, a five-storey RC building located in seismic zone-V is considered with four shear walls. Five different configurations of shear walls viz. bare frame, shear wall symmetrically placed at exterior bays (centrally), at core and adjacently placed in exterior of the building, are considered. These frames are analysed for seismic forces to assess performance in terms of base shear, storey drift, member forces and joint displacements. The frame with shear walls at core and centrally placed at exterior bays showed significant reduction of order 29% to 83% in lateral displacement. The reduction in bending moments is approximately 70% to 85% for interior and perimeter columns respectively. Shear and axial forces in columns have reduced by 86% and 45% respectively. Based on such results, the best placement of shear walls in building plan is suggested.

D. K. Jain and M. S. Hora (2014),. The interaction analysis is carried out with and without shear wall to investigate the effect of inclusion of shear wall on the forces in the footings due to differential settlement of soil mass. The frame and soil mass both are considered to behave in linear elastic manner. It is observed that the soil-structure interaction effect significantly alters the axial forces and moments in the footings due to the differential settlement. The non-interaction analysis of space-frame-shear wall suggests that the presence of shear wall significantly reduces bending moments in most of the column footings but the interaction effect causes restoration of the bending moments to a great extent.

Jayashree.S.M, R.RakulBharatwaj, Helen Santhi.M, (2013) ,These studies generally help in enhancing the understanding of structural behaviour to blast load. In this paper an attempt has been made to use Slurry Infiltrated Fibre Reinforced Concrete (SIFCON), a type of FRC with high fibre content as an alternative material to Reinforced Cement Concrete (RCC). SIFCON has high energy absorption capacity, higher strength and it is highly ductile. Space framed models are developed and time history analysis is carried out for blast load using the software package SAP 2000. The properties of SIFCON and RCC are derived from the experiments. The dynamic characteristics such as fundamental frequency, mode shapes are evaluated. The displacement time history response of frames with SIFCON and RCC due to blast load is compared. The results showed that the reduction in the displacement of about 25-30 % is achieved using SIFCON.

Ahmed Elmarakbi n, Yee Xin Long, John MacIntyre (2013) describes this paper presents finite element simulations of the crash behaviour and the energy absorption characteristics of thin S-shaped longitudinal members with variable cross-sections made of different materials to investigate the design of optimized energy-absorbing members. Numerical studies are carried out by simulation

via the explicit finite element code LS-DYNA [1] to determine the desired variables for the design of energy-absorbing members. The specific energy absorption (SEA), the weight of the members and the peak force responses during the frontal impact are the main measurements of the S-shaped members' performance. Several types of inner stiffening members are also investigated to determine the influence of the additional stiffness on the crash behaviour.

Ms. S. D. Ambadkar & Prof. Dr. P. S. Pajgade, (2012) This paper discusses LCC of RCC Industrial Building (G+2) compared with LCC OF Steel Industrial Building (G+2) with Hollow Columns & steel Deck & LCC of Steel Industrial Building with I-section columns & steel deck.

Shilin DONG (2012) The application of prestressing technology and the innovation of structural concepts and configurations are also associated with modern space structures, including composite space trusses, open-web grid structures, polyhedron space frame structures, partial double-layer lattice shells, cable-stayed grid structures, tree-type structures, prestressed segmental steel structures and so forth. This paper provides a review of the structural characteristics and practical applications in China of modern rigid space structures, modern flexible space structures and modern rigid-flexible combined space structures.

K.K.Sangle, K.M.Bajoria, V.Mhalungkar (2009) In this paper the linear time history analysis is carried out on high rise steel building with different pattern of bracing system for Northridge earthquake. Natural frequencies, fundamental time period, mode shapes, inter story drift and base shear are calculated with different pattern of bracing system. Further optimization study was carried out to decide the suitable type of the bracing pattern by keeping the inter-story drift, total lateral displacement and stress level within permissible limit. Aim of study was to compare the results of seismic analysis of high rise steel building with different pattern of bracing system and without bracing system.

Hou Guangyu, Chen Binlei, Miao Qisong, Liu Xiangyang, Huang Jia (2008) This paper presents the design, research and related joints' details of a 31-story composite frame-core wall structure, which is located in Beijing City, a region of seismic fortification of 8 degree. In order to improve the ductility, bearing capacity of the core walls and to ensure inelastic deformation capacity of the longitudinal coupling beams carried steel trusses, proper steel frames were embedded within the longitudinal core walls. The results of elasto-plastic time-history analysis under the action of rarely occurring earthquake are very close to the data of shaking table test. Experimental results show that there are no obvious cracks in the core walls, spalling of concrete and local buckling of reinforcement at the bottom of the core wall's boundary elements and the composite columns at the perimeter have not been observed, even the elasto-plastic story drift angle has reached 1/101, the whole structure has better seismic performance. However, higher strain measurement of the floor beam end during the rarely occurring earthquake shows partial restraining moment should be considered at the connection.

Kim, Jin-Wool, Kim, Taek-Soo, and Lee, Yong-Hee (2006) In this paper, test model consists of uniform pyramids with ball type joint, the structure is shaped and erected into its final curved space structures. The feasibility of the proposed post-tensioning technique and the reliability of the established geometric model were confirmed with finite element analysis and experiment for a small-scale test model. As a result, proposed post-tensioning technique could be applied the shaping formation of space structure with ball type joint, so we can know the characteristic of the behaviour in shaping test for practical design purposes, it should be an economic and reasonable method compare to conventional construction method including the heavy crane and scaffold.

Naoki NIWA, Seiji AKIYAMA, Kazunari MAKIBE and Akio TOMITA (2004) These characteristics give flexibility to building planning and future possible renovations. The seismic response analysis results illustrated that the earthquake-resistance standards of Japan, as a severely seismic country, could be satisfied, and the boundary beams reduced the seismic response. The loading tests confirmed that the shear strength and bending characteristics of the earthquake-resisting walls with built-in steel could be evaluated by conventional design equations for reinforced concrete earthquake-resisting walls. It was also verified that the boundary beams proposed had a large equivalent damping factor and could decrease damage compared with boundary beams of normal cross-sections.

R. Soegiarso (2003) The structure is subjected to wind loading according to the Uniform Building Code (UBC) in addition to the vertical loads due to dead and live loads. A scaling procedure is developed that results in fast convergence. The algorithm is applied to minimum weight design of four large high-rise steel building structure

s ranging in height from 20 to 81 stories and in size from 1,920 to 9,245 members. A comparison of designs of space moment-resisting frames based on the AISC LRFD code with those based on the AISC Allowable Stress Design (ASD) code shows the former results in a lighter structure for the examples presented. Nowadays architecture is designed in simple shapes, cube form and geometrical volume. This is caused by structure system in a building; we must follow structure to achieve design forms. This is a time for the rejuvenation of architectural forms, shapes and space. In some countries there is earthquake problem, which need a structural system that can give better resistance against earthquake and ensure a stable building.

Dr Kumar (2001) The structure is subjected to wind loading according to the Uniform Building Code (UBC) in addition to the vertical loads due to dead and live loads. A scaling procedure is developed that results in fast convergence. The algorithm is

applied to minimum weight design of four large high-rise steel building structures ranging in height from 20 to 81 stories and in size from 1,920 to 9,245 members. A comparison of designs of space moment-resisting frames based on the AISC LRFD code with those based on the AISC Allowable Stress Design (ASD) code shows the former results in a lighter structure for the examples presented.

Fattah K. Abbas Adel Abdul Jabbar AL-Waily (2000) It is concluded that in spite of the fact that the amount of differential rotation between beam and column is relatively small in the loaded frame structures, this differential rotation has a significant effect on the geometrical behaviour of frame structures and consequently on the design of their elements. It has been shown that the consideration of semi-rigid connections in the analysis of frame structures is of great importance.

Ioannis Mitsos, Simon D. Guest, Pete Winslow (2007) This paper describes an experimental investigation into a half-scale structural model of a solar collector double layer tensegrity space grid that was originally proposed to cover the new National Opera House in Athens, Greece. The structural scale model has a 5m span with cubic modules of 1.25m edge length. The key purpose of the experiment is to investigate the construction sequence, and, in particular, the pre-stressing of the structure. A novel pre-stressing scheme is used, where the top and bottom horizontal members are jacked apart, and a vertical compression member is lengthened. In practice, verification of pre-stressing is important, and a practical technique for measuring prestress in the diagonal members in the field through vibration measurements is described.

### III. CONCLUSIONS

This review paper provides information on various factors that help in understanding of factors effecting design and analysis of space frame structure. The lateral load resisting capacity of frame increases significantly in case of steel frame introduction as is clear from the storey developed maximum displacements. As compared to bare frames, braced frame has drastically less value of maximum lateral displacements also the values are within the permissible limits. Fully braced frame as well as optimally braced frames with soft storey is found to be more flexible at intermediate level than that at ground level. When provision of soft storey is a must at that time optimally braced frames are found to be best suited compared with the fully braced structure with soft storey, partially braced frames satisfying the adopted acceptance criteria revealed that as single bay braced and two bay braced yield optimum positions from view point of minimising the cost. It also increases flexibility of the structure so as to have displacements within permissible limits. For cross and single diagonal type frame axial force in penultimate column is reduced as compared to end column. The same result is observed for different height of the space frame structure.

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### REFERENCES

- [1] Calladine, C. R. (1978). "Buckminster Fuller's Tensegrity Structures and Clerk Maxwell's Rule for the Construction of Stiff Frames."
- [2] Clarke, M. J. and Hancock, G. J. (1995). "Test and Nonlinear Analysis of Small-scale Stressed-arch Frames."
- [3] June 14-16, 2006 - Montréal, Canada Joint International Conference on Computing and Decision Making in Civil and Building Engineering.
- [4] Dehdashti, G., and Schmidt, L. C. (1996). "Dome-shaped Space Trusses Formed by means of Post-tensioning." *Journal of Structural Engineering*,
- [5] Kim J. W. (2000). "Analysis and Test of Dome-shaped Space Truss." *Journal of the Korea Society of Civil Engineers*.
- [6] Kim J. W. (2001). "Shape Creation and Ultimate Load Test of Space Truss by Means of Posttensioning." *Journal of the Architectural Institute of Korea*.

- [7] Kim, J. W., and Hao, J. (2002). "Behaviour Characteristic of a Full-size Scale Pyramidal Space Truss Unit." KSCE Journal of Civil Engineering.
- [8] Kim J.W., Hao and Lee (2001). "New Attachment Device for Post-tensioning of Full Size Scale Space Truss.
- [9] Kim, J. W. and Schmidt, L. C. (2000). "Test of Deployable Dome-Shaped Space Truss." International Conference on Computing in Civil and Building Engineering.
- [10] Kim, J. W., Kim, J. J., and Lee, J. W. (2002). "Form Finding and Experiments for Three Types of Space Trusses." Space Structures.
- [11] Kim, J. W., Kim, J. J., and Rhew, H. J. (2004). "Analysis and Experiment for Self-erected Hypar Space Truss." Proceedings of the Second International Conference on Structural Engineering, Mechanics and Computation.
- [12] Kim, J. W., Kim, J. J., and Rhew, H. J. (2006). "Analysis and Experiment for the Formation and Ultimate Load Testing of a Hypar Space Truss.
- [13] Kim J. W., Kwon M. H., and Rhew, H. J. (2005). "Shaping Formation and Nonlinear Analysis of Mero Jointed Space Structure with Multi-directional Joint."
- [14] Schmidt, L. C. & Selby, S. (1999). "Domical Space Trusses and Braced Domes: Shaping, Ultimate Strength and Stiffness."
- [15] Schmidt, L. C. and Steven Selby (2001). "Shape Formation of some Dome-like Space Trusses."
- [16] Alvarez, F. Guichard, P.-L. Lions, and J.-M. Morel, "Axioms and fundamental equations of image processing.
- [17] J. Babaud, A. P. Witkin, M. Baudin, and R. O. Duda, "Uniqueness of the Gaussian kernel for scale-space filtering",
- [18] J. Burt and E. H. Adelson, "The Laplacian pyramid as a compact image code",
- [19] J. Canny, "A computational approach to edge detection",
- [20] Chehikian and J. L. Crowley, "Fast computation of optimal semi-octave pyramids", in Proc. 7th Scandinavian Conf. on Image Analysis, (Aalborg, Denmark), pp. 18-27, Aug. 1991.

