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Seismic Analysis of Modified Industrial Structure using Bracings and Dampers A Review

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ABSTRACT

Resistance of structures against earthquake plays an extensive role in construction industry. A structure should consist of strength, stability and ductility to accommodate both horizontal and vertical loadings. Horizontal loading leads to the production of sway and further results in vibration and storey drift. Strength and stiffness are two major keys for any structure to resist gravity and lateral loads. Provision of bracings or dampers to any structure contributes to lateral stability. After assigning dampers or bracings, the general system changes to lateral load resisting system (LLRS). The present work involves in proposing the suitability of type of damper or bracing for controlling the seismic activity on industrial structures in respective seismic zones II of India. Industrial structures also associate high dead load as it provides residence to heavy sized members. Therefore, this is necessary to investigate seismic response of buildings with various bracings and dampers to control vibration, lateral displacement and storey drift. Natural time period, frequency, roof displacements are the major parameters considered for observing response of structures. Response spectrum analysis of 3D industrial structure with distinct concentric bracings and dampers using SAP 2000 will be carrying in this research under respective base shear.

Keywords : Steel Structure, Analysis, Industrial Frame, Drift, Seismic Zone

I. INTRODUCTION

Earthquakes are perhaps the most unpredictable and devastating of all natural disasters. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. An earthquake may be defined as a wave like motion generated by forces in constant turmoil under the surface layer of the earth (lithosphere), travelling through the earth's crust. It may also be defined as the vibration, sometimes violent, of the earth's surface as a result of a release of energy in the earth's crust. This release of energy can cause by sudden dislocations of segments of the crust, volcanic eruption, or even explosion created by humans. Dislocations of crust segments, however, lead to the most destructive quakes. In the process of dislocation, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake at varying speed, causing the earth to quiver or ring like a bell or tuning fork. The concern about seismic hazards has led to an increasing awareness and demand for structures designed to withstand seismic forces. In such a scenario, the onus of making the building and structure safe in earthquake-prone areas lies on the designers, architects, and engineers who conceptualize these structures. Codes and recommendations, postulated by the relevant authorities, study of the behavior of structures in past earthquakes and understanding the physics of earthquake are some of the factors that helps in the designing of an earthquake resistant structure.

II. LITERATURE REVIEW

In this study presenting review of following:

1. Ramamurthy and Nagababu (2019)[12] The research paper presented a three dimensional geometry of the workstation gantry crane using catia. Then analysis of section beam, the part which is used to carry the loads in gantry crane, is carried out by using finite element method in ansys software for different loads apply on I-section, clamp, hook and at different positions. Using materials in this project structural steel, 34crmo4 chrome steel, carbon steel 1020, aisi 4130. The load bearing capacity of i-section beam was estimated by placing the loads at different positions i.e. (from left end of isection as 1300mm, 4300mm and 5300mm) and by observing von-missies stresses, shear stress, and deflections generated from static analysis in ansys 14.5. The results stated that the von-missies stresses, vonmisses, shear stress and deflections in static analysis using ansys 14.5. For the load of 15000n load considering the i-section beam maximum values at three positions. By placing different materials (carbon steel 1020, chrome steel, structural steel, aisi 4130) at different positions. Conclusion stated that chrome steel is the best material because of less von-misses stress, shear stress, and total deformation also it is observed that chrome steel is the suitable for gantry crane .with respect to both static and modal analysis.

2. Ravali and Poluraju (2019)[4] Proposing the suitability of type of damper or bracing for controlling the seismic activity on industrial structures in respective seismic zones III and V of India. Industrial structures also associate high dead load as it provides residence to heavy sized members. Therefore, this is necessary to investigate seismic response of buildings with various bracings and dampers to control vibration, lateral displacement and storey drift. The conclusion stated that As stiffness of structure increases, time period decreases. While comparing bracing and damper, bracing reduces the time period. Acceleration is inversely proportional to time period and as time period decreases, acceleration of structure increases. Similar to acceleration, frequency also inversely proportional to time period. X- Bracing system greatly influences the base shear of structure and reduces it. Using of X-bracing greatly reduces the lateral displacement of the structure when compared to other bracings and dampers. Also, dampers require regular maintenance for their effective behaviour.

3. Rahaman et. al. (2018)[6] The research paper focused on the main modelling aspects and results from analysis of seismic performance upon integration with site-specific hazard, the structural risk assessment, that is, a probability of failures. These buildings require large and clear areas unobstructed by the columns. The large floor area provides sufficient flexibility and facility for later change in the production layout without major building alterations. The industrial buildings are constructed with adequate headroom for the use of an overhead traveling crane. There are various international codes available for the design of steel structures.The results stated that point of confinement state strategy is more solid and efficient than the working pressure technique for planning structure. The consequences

of the point of confinement state strategy for twisting minute and load conveying limit is higher than working pressure technique. The consumption of steel is less in LSM with respect to WSM. For same working forces, WSM will require higher steel section than LSM. Working stress method is simple to use but does not give consistent values of a factor of safety. That is the reason Limit states methods were developed. The limit states provide a checklist of the basic structural requirements for which design calculations may be required. Limit states design, by providing consistent safety and serviceability, ensures an economical use of materials and a wide range of applications.

4. Belleri et. al. (2017)[1] The influence of overhead cranes with a hanging mass under earthquake type loading, considering the Emilia 2012 seismic sequence. The structural layout of precast concrete industrial buildings typical of the Italian territory is consid-ered. The equations of motion describing the behavior of the hoist load are derived, and a sensitivity analysis is carried out on simplified 3 degrees of freedom systems by solving the governing differential equations. The influence of various parameters on the roof displacement and on the horizontal load transferred by the hanging mass is addressed. The considered parameters are the relative damping of the hanging mass, the length of the hoist ropes, the earthquake record, the hysteretic type of the plastic hinges at the column base, and the behavior factor of the structural system. Results showed a beneficial effect of the hoist mass in the longitudinal direction (i.e., along the runway beams direction), while a negative effect was recorded in the transverse direction (i.e., along to the crane direction) for in-plane flexible roofs, in particular because of the increase of torsion displacements induced by the hoist load oscillations. This phenomenon is not present in the longitudinal direction due to the symmetry of the position of the hoist load and to the presence of a single bay.

5. Gupta and Baig (2017)[5] The research paper proposed to carry out the design of an industrial steel storage shed by limit state method based on IS 800-2007 (LSM) and comparing the results with the same obtained by working stress method based on IS 800-1984, for a structure with the same dimensions & loading. An industrial shed of steel truss of 48m x 16.0m having a bay spacing of 4.0m with a column height of 11m. is considered in the Industrial area of East Delhi. The fink type roof trusses have the span of 16 meters. The structure is modeled in STAAD Pro, analysis and design software. A full 3D model is generated. This project is all about analysis of loads & forces acting on the members of the above structure & their design. Loads acting on the structure are gravity loads (dead & live), Crane Loads, wind loads, and seismic loads calculated using Indian Standard code IS 875-1987 (part I), IS 875-1987 (part II), IS 875-1987 (part III) and the section properties of the specimens are obtained using steel table. In this structure snow loads are not considered as Delhi does not encounter snowfall at all. The main aim of the project is to provide which method is economical and provide more load carrying capacity and high flexural strength.The results concluded that limit state method is more reliable and economical than the working stress method for designing structure. The results of the limit state method of bending moment and load carrying capacity are higher than working stress method. The limit states provide a checklist of the basic structural requirements for which design calculations may be required. Limit states to design, provide consistent safety and serviceability.

6. Gowardhan et. al. (2016)[2] In this paper static linear analysis is carried out for high rise steel frame building with different pattern of bracing system. The shear capacity of the structure can be increased by introducing Steel bracings in the structural system. There are 'n' numbers of possibilities to arrange steel bracings such as Diagonal, X, K, Inverted V bracings. A typical 14th- story regular steel frame building is

analyzed for various types of concentric bracings like Diagonal, X, inverted V and K-type and Performance of each frame is carried out through static linear analysis i.e. equivalent static force method. Three types of sections i.e. ISMB, ISMC and ISA sections are used to compare for same patterns of bracing with different position. Results stated that Steel bracings reduce flexure and shear demands on beams and columns and transfer the lateral loads through axial load mechanism. Using Steel Bracing the total weight on the existing building will not change significantly. The braced building of the lateral displacement decreases as compared to the unbraced building.

7. Shengfang et. al. (2016)[17] The research paper presented seismic analysis for steel frame structure with brace configuration using topology optimization based on truss-like material model. The orientations and densities of members in truss-like continuum are optimized and updated by fully-stressed criterion in every iteration. The optimized truss-like continuum is founded after finite element analysis is finished. The optimal bracing system is established based on optimized truss-like continuum without numerical instability. Seismic performance for steel frame structures is derived using dynamic time-history analysis.The results concluded that the optimal bracing system based on truss-like material model avoids numberical instability and shows more details for brace configuration. The common “X” brace and inverted “V” brace are not always optimal. Moreover, the inverted “V” brace is more acceptable than the single-bar brace when span is twice as much as story height. The frame structures with optimized braces are more efficient to reduce the drifts. Further, beams first undergo yielding in original steel structure, nevertheless, braces yield firstly in structures with braces. Moreover, brace can mitigate seismic damage.

8. Khaleel and Kumar (2016)[13]The research paper presented the analysis of the effect of seismic force on Regular and Irregular Steel framed high rise building with different bracing system and also to find the best bracing system. The building is modeled and analyzed using ETABS and sections are selected based on their capability to control the maximum lateral storey displacements. The Zone V as per IS 1893-2002 is selected for the study. Analysis was carried out by Equivalent Static Method and Response Spectrum Method considering parameters such as, displacement and base shear. The results concluded that the bracing in the building reduces the storey displacement in both regular and irregular building as compared to the building without bracings for lateral loads. For regular and irregular building, Cross bracings gives less storey displacement. Cross bracings has more base shear and Knee bracing has the least amount of base shear. Use of bracing system increases the stiffness of the structure and attracts more lateral force.

9. Karthik et. al. (2016) [8]The research paper presented the effect of seismic loading in 15 storey regular bare building using ETABS software. The model adapted different types of bracings such as diagonal, braced diagonal, X, K, K with bracing, chevron, braced chevron, V, eccentric diagonal and Knee bracings. The seismic response are evaluated by using equivalent static analysis, response spectrum analysis and linear time history analysis for bhuj earthquake data on Zone- V. The results presented that the displacement and inter storey drift are within limits as per the codal requirements and are reduced in different braced frame models compared with the bare frame models, due to additional stiffness of bracings. The displacement and inter storey drift are less in X and chevron braced regular models compared to other braced models. The storey shear are increased in braced models compared with the bare frame models due to additional mass and stiffness of bracing elements. The displacements and inter storey drifts in regular models are decreased when we provide bracing systems. This indicates that bracings are significantly reduce the amount of forces by increasing the stiffness and ductility of the structure

against seismic forces and also increases strength against the seismic forces. In equivalent static analysis method for regular models, the maximum lateral displacements are reduced after the use of X bracings of about 75.16% and chevron bracings of about 66.11% as compared with the bare frame model. In response spectrum analysis for regular braced models, the maximum inter storey drift reduced to about 79.01% in X bracings at storey 5 and 69.35% in chevron bracings at storey 3 compared with the bare frame model because of in this method overall response of building decreases and stiffness increases. Based on the analysis results in regular and irregular braced models, X bracings and chevron bracings system showed better resistance to seismic forces than the other specified bracing systems.

10. Gupta and Thawari (2016)[10] The research paper presented seismic analysis of Industrial building and the modelling and analysis of the structure was done using Staad.pro. The conclusion derived from the results stated that Analysis and design as grids result in lower beam sizes, Precautions in fabrication and erection can be taken on the site. Higher resistance to the seismic forces occurred in the flexible frame structure by steel fabrication. The bars having yield strength higher than 500N/mm2tend to possess lower percentage elongation which is not acceptable for Seismic prone structures. The sectional properties for ISMB 900 section are not in database and design parameters of Staad.pro 2007 so by using the section as ISMB 600 resist the permissible stresses and the respective bending moments in beam sections.

11. Navya et. al. (2015)[14] The research paper presented the analysis of structural behavior of hangar subjected to lateral loads i.e, both wind load and seismic loads using equivalent static analysis using standard FEM software package ETABS. The study encloses behavior of different truss configuration and different frame sections. The member forces are considered as the main parameter. The results concluded that "one particular truss is efficient because it induces less internal forces". Each type of trusses has varied flow of axial forces through their members as their pattern changes. Hence they are preferred according to the requirement of the structure. But the triangular fink type truss with hollow square tube section is concluded as the most economical truss because it is lightest and induces less internal forces which performs well even under heavy loading as well as the action of lateral loads. RCC columns has increased axial forces wherein portal frame and steel frame show similar behavior and decreased axial forces. However portal frame has least axial forces among all the frame section and is structurally light, economical, easy to fabricate and has less maintenance.

12. Ghogare et. al. (2015)[7] For paper work the equivalent static analysis is carried out for steel building. The seismic analysis & design of multi-storey steel building is carried out using Software Computer Aided Design i.e., (STAAD PRO) .The main parameters consider for comparing wind performance of buildings are bending moment ,shear force ,deflection and axial force. The seismic design of building frame presented in this paper is based on IS:1893:2002, IS:1893:2005 and IS:800:2007 .The building consists of two storey. The selection of arbitrary sections has been done following a standard procedure. Industrial structure analysis consist of five trusses which is four storey two bay steel structure. Complete analysis of structure is done considering Dead Load, Live Load, Wind Load and Seismic load in various combinations a per IS:800:2007, IS:1893:2002, IS:875:1987 etc. Since the structure is symmetrical in nature, some of important analysis remark are highlighted for various load case consideration for outer and inner frame.

13. Andrea et. al. (2014)[3] The research paper examined three numerical analysis techniques namely , uncoupled response spectrum method,

inertial coupled response spectrum method and dynamic coupled response spectrum method. The aim of the study was to evaluate conservatisms and inadequacies associated to each technique. The study concerns the seismic response of an overhead crane supported by a steel frame building exhibiting linear elastic material behaviour and modelled using a three-dimensional finite element mesh. In order to cover a wide range of configurations, different crane and trolley locations and crane loading states are taken into account in the study. Results stated that a correct implementation of crane-carrying structure interaction leads to a reduction of seismic efforts and hence an increase of safety factors regarding integrity (up to 16% for end carriage beams and 33% for principal beams) and of safety factors regarding stability (up to 16% concerning crane uplift and 48% concerning crane sliding). The quantified differences between methods include the conservatism introduced by the broadening of floor spectra for uncoupled method and inertial coupled method. Furthermore, relative displacements between wheels and track on cross travel direction can only be obtained with a model including carrying structure. A preliminary analysis of modal features of primary system and subsystem is useful to identify the importance of interaction as well as to define the effective carrying structure at each direction. A dynamic coupled spectrum analysis carried out on a model including the equipment and the effective carrying structure (i.e. runway beams) should lead to satisfactory results with efficient time-machine resources.

14. Khan and Khalid (2014)[11] The research paper presented non linear push over analysis for high rise steel frame building with different pattern of bracing system. The shear capacity of the structure can be increased by introducing Steel bracings in the structural system. There are 'n' numbers of possibilities to arrange steel bracings such as Diagonal, X, K, V, Inverted V or chevron and global type concentric bracings. A typical 15th- story regular steel frame building is designed for various types of concentric bracings like Diagonal, V, X, and Exterior X and Performance of each frame is carried out through nonlinear static analysis. Three types of sections i.e. ISMB, ISMC and ISA sections are used to compare for same patterns of bracing.The results led to the observation that due to bracing in both direction base shear capacity for V-Brace, Diagonal Brace, X-Brace, increases up to 40-50 % as compared with bare frame model, where as in Exterior X-Brace maximum base shear increases up to 70 % as compared with bare frame model and ISMB Sections gives more base shear compare to angel and channel section for similar type of brace. Bare frame has got more performance displacement and less performance base force when compared to other models. It can be seen that bracings have increased level of performance both in terms of base shear carrying capacity and roof displacement. The V-Brace, Diagonal Brace, X-Brace models has got more performance displacement and less performance base force compared to X-Brace, Exterior X-Brace. X-Brace, Exterior X-Brace models increases the stiffness compare to other models and ISMB Sections gives more stiffness compare to angel and channel sections for similar type of brace. Capacity and demand curve are drawn for steel frames with and without bracings for seismic zone 5, The exterior ISMB X Brace model have increased performance level compare to other types of bracing models and it can also be seen that the frames with bracings have lesser vulnerability compared to the frames without bracings. ISMB Sections gives more Performance point compare to angel and channel section for similar type of brace.

15. Ferro et. al. (2014)[16] Establishing a practical application of dynamic loads caused by rotating equipment on supports with different connections structures using computational models with STRAP software. Models of structures with connections rigid, pinned and semi-rigid, will be made, applying loads of

rotating machines and viewing which support base has the best performance in relation structure versus dynamic loading in accordance with connections. there are well-founded theoretical basis and adequate computational tools the making of an effective and dynamic calculation of the equipment and structure can be simple and with more capacity of the structural engineer to recommend the best structure considering its connections. Then, considering the software STRAP, which is practical for use in research, the calculations of structural dynamics may be more reliable. Finally, the article is suggested as a reference for future calculations of supporting structures of rotating machinery, and as a suggestion we recommend the actual construction of the models.

16. Nikolai et. al. (2014)[15]The standardization of calculated seismic effects on the industrial buildings of nuclear energy facilities (FUNE) with crane loadings was proposed according to the maps of general seismic regionalization OSR-97. A discrete-continuum shell-beam dynamic model of the ISFSI building with cranes and crane loadings from cranes with 160/32 t, 16/3.2 t and 15 t was developed based on the FEM principals. For the dynamic model of the ISFSI building with crane loadings in the 7 magnitude zone, a nonlinear equation of the nth-order seismic oscillations was developed. The equation was solved using the absolutely stable Gear method with the backward differentiation formula. Conclusion The basics of the theory of seismic stability of the spatial structures of industrial buildings with cranes and crane loadings were proposed based on FEM and DAM by integrating the seismic oscillation equations using the Gear method and the LSM equations of motion, which are solved in principal coordinates by applying the orthogonality conditions of Rayleigh. The seismic oscillation equations were solved using DAM and LSM for the ISFSI building with crane loadings. The transition from the displacements to the internal forces and then to the normal and tangent stresses was proposed, which is used by the designer to make decisions according to the chosen strength theory.

17. Sangle et. al. (2012)[9]The research paper carried the linear time history analysis 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. Results presented that bracing element will have very important effect on structural behavior under earthquake effect. Due to bracings in both direction base shear increases up to 38%. The displacements at roof level of the building with different bracing style is reduces from 43% to 60%. Modal time period is also reduced up to 65%. The diagonal brace-B shows highly effective and economical design of bracing style.

III. CONCLUSION

The researchers have tried to find the variation in forces which occurs due to bracings and dampers, following are the outcomes of literature review:

1 Determine that frames with bracings and dampers will make the structure stable.
2 That structure considering dampers is more stable and symmetric.
3 Difference in frame without supporting members and with supporting members shows variations in deflection.

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