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Comparative Analysis of Steel Structure under Seismic and Blast Loading

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***Abstract*— Rapid urbanization and increasing demand for performance based design have necessitated the evaluation of steel buildings under both conventional and extreme loading conditions. This study is to investigate comparative effect of seismic and blast loading on a G+10 steel structure using ETABS and LSDYNA software. For seismic analysis, three structural configurations bare moment-resisting frame, concentrically braced frame & steel frame with reinforced concrete shear walls are modeled & analyzed using ETABS in accordance with relevant Indian seismic provisions. The structural responses are evaluated in terms storey displacement, storey drift, base shear and internal force demand. To investigate behavior under extreme loading corresponding to three dimensional numerical where three models are developed in LSDYNA to simulate blast effects using pressure–time histories representative of near field explosions. The blast response is assessed based on peak displacement, stress distribution, energy dissipation and damage patterns. A comparative interpretation is then made between seismic and blast performance for each structural configuration. Results indicate that inclusion of bracing and shear wall significantly enhances stiffness, reduces lateral deformation and improves overall structural resilience under both loading scenarios.**

***Keywords*— Steel building, Seismic analysis, Blast loading, Braced frame, Shear wall, Lateral load resisting system.**

I. Introduction

A. General

Increased construction of high rise steel buildings raised concerns regarding safety under extreme loading conditions such as earthquake & blast events. While seismic loading is well addressed in design codes, blast loading is a sudden where high intensity phenomenon that can cause severe local and global damage. Hence evaluating the comparative effects of seismic and blast loading is essential for achieving multi hazard resistant structural design. In this study G+10 storey steel building is analysed to investigate its response under seismic and blast loading conditions. Six structural configurations are considered as conventional steel moment resisting frame, steel frame with cross bracing & steel frame with shear walls.

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All models are designed with identical geometry, material properties and gravity loads to ensure a consistent comparison. Seismic analysis is carried out using etabs software and design horizontal seismic coefficient given by equation (1),

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g} \qquad (1)$$

Where, Z is seismic zone factor, I is importance factor, R is response reduction factor and S_a/g is average response acceleration coefficient.

Total design base shear is calculated using equation (2),

$$V_b = A_h x\ W \qquad (2)$$

Where, W is seismic weight of building.

Blast analysis is performed using LS-DYNA by applying time dependent blast pressure governed by scaled distance relation using equation (3),

$$Z = \frac{R}{W^{1/3}} \qquad (3)$$

Previous studies demonstrated that the significance of structural configuration and soil structure interaction on blast response. Ref [1] & ref. [2] studied soil structure interaction significantly influences progressive collapse behaviour of steel structure under blast load particularly for asymmetric configurations. Ref [3], ref. [4] & ref. [5] studied the increased blast intensity and reduced stand-off distance lead to a sharp rise in storey displacement and drift while shear walls and steel bracing effectively reduce structural response. Taller buildings are more sensitive to dynamic load such as blast and earthquake forces and provision of shear walls at edge locations significantly reduces structural displacement studied from ref. [6] , ref. [7] & ref. [8].

Based on reviewed literature it is evident that limited studies have addressed a unified comparative assessment of steel buildings under both seismic and blast loading using consistent modelling approaches. Present research aims to bridge this gap by comparing performance of different lateral load resisting system in G+10 steel building under seismic loading using ETABS and blast loading using LS-DYNA thereby contributing to safer and more resilient steel structural design.

III. METHODOLOGY

A. General

This study begins with creating three dimensional numerical model of G+10 storey steel building using ETABS & LS-DYNA software. Initially new project is created grid lines, storey levels and overall building geometry are defined according to the selected plan dimensions and storey height. Structural material properties such as structural steel grade are assigned and appropriate steel sections are selected for beams, columns, bracing members and shear wall elements to ensure realistic structural behaviour during analysis. Total six model are created, three model for seismic analysis and other three for blast analysis. Three different types of structural configurations are modelled to evaluate influence of lateral load resisting systems conventional steel moment resisting frame, steel frame with cross bracing and steel frame with shear walls. All models are developed with identical geometry, member properties and gravity loading conditions so that comparative assessment remains consistent and reliable.

Dead, live and other applicable loads are assigned as per relevant Indian Standard codes to simulate actual service conditions. Seismic loading is defined in ETABS in accordance with IS 1893 (Part 1): 2016 [11] and appropriate load combinations are generated to capture critical seismic response of structure. Boundary conditions are assigned as fixed supports at base level to represent foundation restraint. After defining all modelling parameters, seismic analysis is performed to obtain structural response quantities such as storey displacement, storey drift, base shear, bending moments & axial forces. For blast analysis same structural configurations are modelled in LS-DYNA using suitable finite element idealization by referring IS 4991:1968[12]. Blast loading is applied in form of time dependent pressure time histories based on equivalent TNT charge weight and stand-off distance. Nonlinear material behaviour and dynamic response are captured during analysis. The results obtained from both seismic and blast analyses are evaluated and compared to assess effectiveness of cross bracing and shear wall systems improving structural performance under extreme loading conditions.

B. Design parameter

The present study considers six numerical models of a G+10 storey steel building to evaluate its performance under seismic and blast loading. Each building model has a uniform floor area of 240m² with typical storey height of 3m resulting overall building height of 33m. Structural system adopted a steel moment-resisting frame. While structural steel of grade Fe 500 is adopted for beams, columns and bracing members all design of steel members is carried out in accordance with IS 800:2007 using limit state design approach [13]. The slab thickness is taken as 125mm. Beams are modelled using ISMB 300 sections, columns using ISMC 400 sections, and cross bracing members are provided using ISA 100×100×10 sections. Slab load is considered as 3.5KN/m² while floor live load is taken 3KN/m². Live load 1.5KN/m² is applied on roof slab [10]. Superimposed dead load on floor is assumed as 1.5KN/m² [9]. Seismic analysis is carried out as per IS 1893 (Part 1): 2016 [11] for zone V with zone factor 0.36. An importance factor 1.2 and response reduction factor 5 are adopted for analysis. Medium soil condition (soil type II) is assumed for all seismic evaluations [12]. Blast loading is defined using an equivalent TNT charge weight 100kg with a stand-off distance 20m. The peak side on overpressure is considered as 0.81kg/cm² and a drag coefficient of 0.33KN/m² is adopted for blast force calculations. These modelling and loading parameters form basis for evaluating and comparing seismic and blast performance of the steel building configurations.

C. Model Configurations

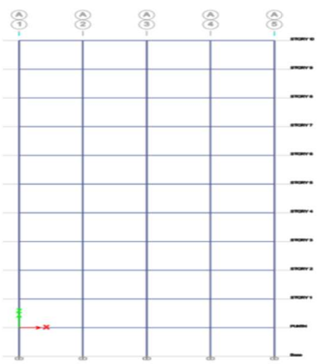

Figure 1. Unbraced frame Model 1

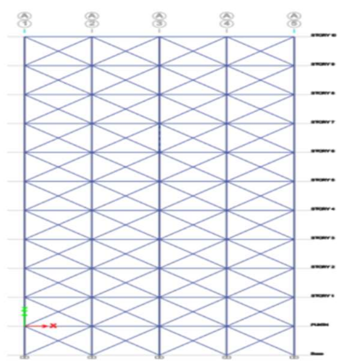

Figure 2. Cross braced Model 2

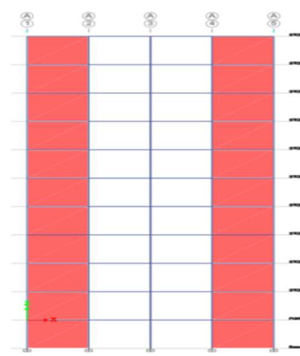

Figure 3. Shear wall Model 3

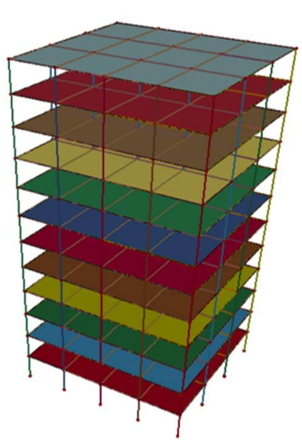

Figure 4. Unbraced frame Model 4

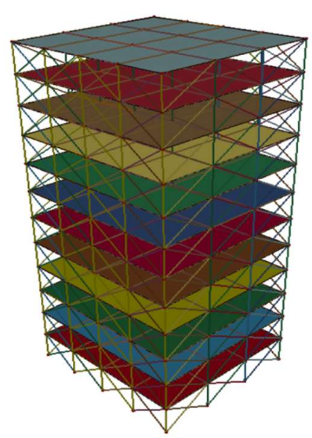

Figure 5. Cross braced Model 5

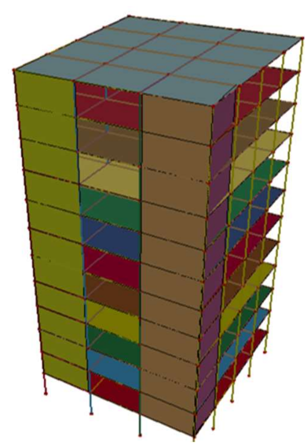

Figure 6. Shear wall Model 6

The above six figures illustrate that analytical models of a G+10 storey steel building developed for present study using ETABS and LS-DYNA software. Figures 1 to 3 represent ETABS models which are considered for analysis comprising an unbraced steel moment resisting frame. Steel frame provided with concentric cross bracing and steel frame integrated with shear walls. Figures 4 to 6 shows corresponding LS-DYNA models of same building configurations adopted for blast load analysis namely unbraced frame, cross braced frame & shear wall system. In all this six models overall geometry, bay spacing, storey height, material properties and member sections are kept identical to ensure consistency between seismic and blast analysis. Unbraced frame system is considered as reference model to evaluate effectiveness of lateral load resisting mechanisms. Cross bracing frame system introduced to enhance lateral stiffness & energy dissipation through axial action of bracing members while shear wall system is incorporated to provide increased lateral strength and improved load transfer characteristics. This uniform modelling approach allows a direct comparison of structural performance and enables a clear assessment of the influence of bracing and shear wall systems on behaviour of steel buildings under seismic and blast loading conditions.

IV. RESULTS

A. Storey Displacement

Storey displacement represent lateral movement of a building at each floor level due to applied dynamic loads and is an important indicator of overall structural stiffness in seismic or blast resistance. In present study storey displacement responses of six different models were evaluated under seismic loading using ETABS and under blast loading using LS-DYNA. The following figure shows storey displacement result, figure 7 & figure 8 is for ETABS software result and figure 9 & figure10 is for LSDYNA software result.

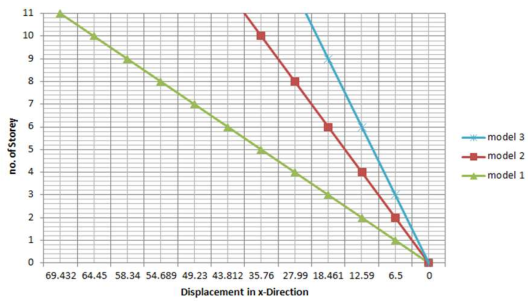

Figure 7. Maximum Storey Displacement in X Direction

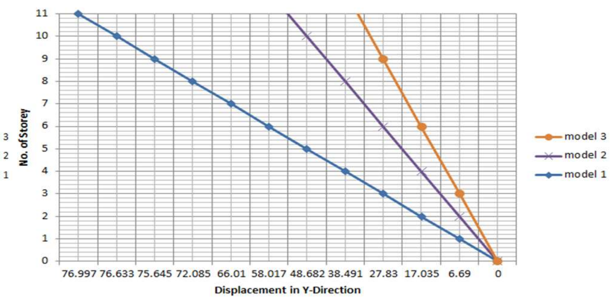

Figure 8. Maximum Storey Displacement in Y Direction

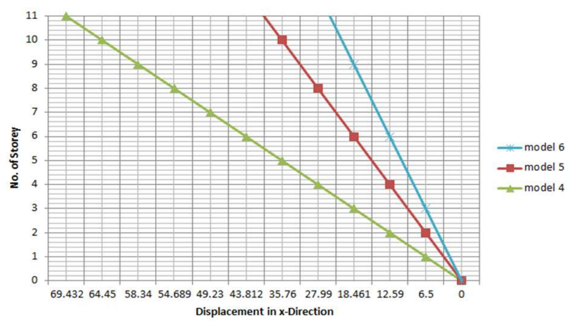

Figure 9. Maximum Storey Drift in X Direction

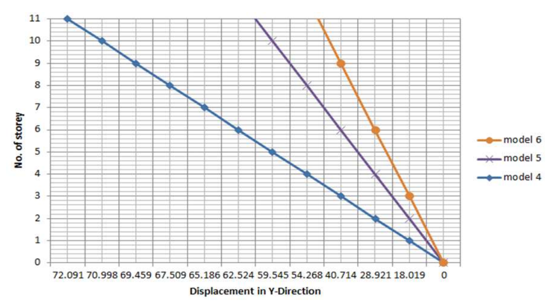

Figure 10. Maximum Storey Drift in Y Direction

Figure 7 shows storey displacement in X direction obtained from ETABS under seismic loading. The unbraced frame exhibits maximum displacement along height of the building due to lower lateral stiffness. The cross-braced frame shows a noticeable reduction in displacement while shear wall system records minimum displacement indicating highest lateral stiffness. Figure 8 presents storey displacement in Y direction for seismic loading.

A similar trend is observed where unbraced frame shows highest displacement followed by cross-braced frame. The shear wall system effectively controls lateral movement in Y direction. Figure 9 illustrates the storey displacement in X direction obtained from LS-DYNA under blast loading. The unbraced frame undergoes large lateral displacements due to the impulsive nature of blast forces. The cross-braced system performs better by limiting deformation while shear wall system shows least displacement. Figure 10 shows storey displacement in Y direction under blast loading. The unbraced frame remains most vulnerable whereas cross-braced and shear wall systems significantly reduce blast induced displacements.

B. Storey Drift

Storey drift is defined relative lateral displacement between two consecutive floors and is critical parameter for assessing structural damage, serviceability and safety under dynamic loading conditions. In present study storey drift responses of six steel building models were evaluated under seismic loading using ETABS and under blast loading using LS-DYNA. The following figure shows storey displacement result, figure 11 & figure 12 is for ETABS software result and figure 13 & figure 14 is for LSDYNA software result.

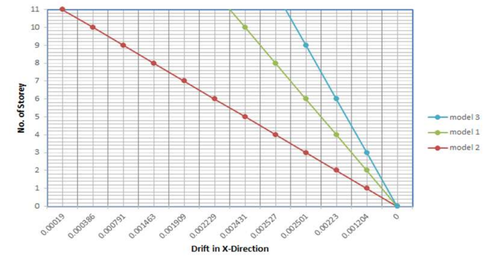

Figure 11. Maximum Storey Displacement in X Direction

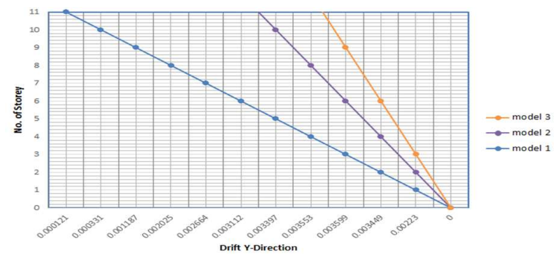

Figure 12. Maximum Storey Displacement in Y Direction

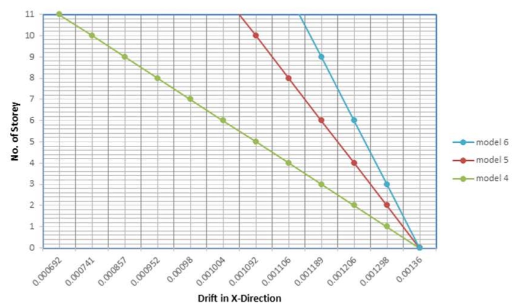

Figure 13. Maximum Storey Drift in X Direction

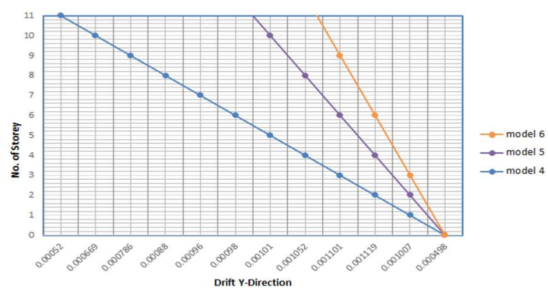

Figure 14. Maximum Storey Drift in Y Direction

Figure 11 presents storey drift in X direction for seismic loading. The unbraced frame experiences higher drift values especially at upper storeys. The cross-braced system reduces drift while shear wall system maintains lowest drift values throughout the building height. Figure 12 shows storey drift in Y direction under seismic loading following a similar pattern with the shear wall system providing the most stable response. Figure 13 illustrates storey drift in X direction under blast loading. The unbraced frame shows high drift demand whereas cross braced frame shows improved performance. The shear wall system effectively limits drift under blast effects. Figure 14 represents storey drift in Y direction under blast loading. The shear wall system consistently shows lowest drift followed by cross braced frame while unbraced frame shows maximum deformation.

V. Discussion of Results

The six analytical models highlight the performance of G+10 steel buildings under seismic and blast loading for different lateral load-resisting systems. ETABS results show that the unbraced frame experiences the largest inter-storey drift and displacement, reflecting low lateral stiffness. Cross bracing improves stiffness, reduces drift and enhances energy dissipation, while the shear wall system provides the highest stiffness and minimum deformation, effectively controlling seismic response. Similarly, LS-DYNA results under blast loading indicate that the unbraced frame undergoes maximum nodal displacement and stress, whereas cross-braced and shear wall systems limit displacement and improve stress distribution. Overall, the shear wall system performs best, followed by the cross-braced frame, while the unbraced frame shows the highest displacement and drift under both seismic and blast loading. Future studies may explore different bracing layouts, shear wall arrangements and varying blast intensities to optimize steel building design.

V. Conclusion

A comparative analytical study was carried out on G+10 storey steel buildings subjected to seismic and blast loading using ETABS and LS-DYNA software, considering regular, braced, and shear wall structural configurations. All models were developed with identical storey height, floor area, material properties and loading conditions to ensure a consistent basis for evaluation. The seismic analysis results indicate that the regular steel frame exhibits higher inter-storey drift compared to braced and shear wall system reflecting its relatively lower lateral stiffness. Introduction of bracing systems enhances energy dissipation and leads to significant reduction in displacement response, while incorporation of shear walls provides maximum stiffness and results in the least deformation under earthquake loading. Blast analysis results further reveal that the regular frame experiences higher stress levels and larger deformations, whereas the braced and shear wall configurations effectively limit the structural response under blast effects. Among all configurations, the shear wall system demonstrates superior performance under both seismic and blast loading by efficiently controlling displacements and improving overall structural stability. Variations in base shear and internal force distribution are observed across different configurations, with bracing and shear wall systems contributing to improved load transfer mechanisms and enhanced structural resilience. The study highlights the critical role of lateral load resisting systems in high rise steel buildings for mitigating effects of dynamic hazards and recommends the incorporation of bracing or shear walls to achieve improved structural performance under multiple dynamic loading conditions. Future research may focus on investigating alternative bracing layouts, different shear wall arrangements and varying blast intensities to further optimize structural design strategies.

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