"A REVIEW STUDY ON STEEL STRUCTURE SUBJECTED TO BLAST LOADING"

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Abstract - The recent terrorist assaults on the infrastructure have severely damaged property and lives, necessitating in-depth study of the progressive collapse analysis of multi-story buildings subjected to blast loading. Typically, much of the research is centered on Alternate Path Method (APM) with sudden column removal, ignoring the optimal site of the blast loading. A 3D model of a 12-story steel building with a direct simulation of the blast load is suggested in this thesis. Additionally, the effect of blast loading at various places has been investigated.

Vehicle-borne and package-borne blast events have both been taken into consideration. The blast load is analytically determined by the numerical model of the structure, which was developed using the "SAP 2000" software. The published example of a tubular steel beam subjected to blast loads is used to validate the numerical model. On the basis of the results of the final analysis, suggestions have been made to prevent the collapse of steel buildings.

Key Words: **Blast load, Displacement, Shear force, Bending moment, SAP 2000, ABAQUS, ATBLAST.**

1. INTRODUCTION

While it may not be possible to totally prevent terrorist attacks on buildings, there are many ways to greatly reduce the damage that these assaults do to buildings and other facilities. Finding the approaches that are most likely to be successful in limiting the negative impacts of the assaults requires an understanding of the building, its intended use, and any potential hazards brought on by terrorist attacks. When compared to the total lifetime costs of the building, the cost of enhancing it for a "certain level" of resistance against terrorist attacks may not be considerable (including the land value and security monitoring). Several components of terrorism risk management are discussed in this chapter together with related financial and technological legal concerns.

A bomb explosion inside or around a building can have catastrophic results, causing interior or external building components to be damaged or destroyed. Large framework, walls, doors, and windows are destroyed, and building services are interrupted.

The occupant may sustain injuries or lose their lives as a result of the blast's debris, fire, and smoke impact.

Building damage from bombs is influenced by the type and design of the structure, the material utilised, the location's explosive device's range, and the charge weight.

The case studies, which are drawn from a variety of nations, are by no means exhaustive because there may be many more explosions in the future and more reports of collateral damage to building subsystems.

2. LITRETURE REVIEW

1. Probabilistic Progressive Collapse Analysis Of Steel Frame Structure Against Blast Loads

   Author: Yang Ding, Xiaran Song, Hai tao zhu

   Journal: Engineering structure (2017)

The purpose of this paper is to examine a study of the progressive collapse of a steel frame building with a ten-story seismic design that was attacked by a vehicle-borne explosive device. In this study, the collapse potential of a structure is assessed using a two-step process.

The sophisticated Delayed Rejection Adaptive Markov Chain Monte Carlo Simulation algorithm first assesses the structural damage. With the aid of the program LS-DYNA, a numerical model of a steel building is created in the second step. In second stage, two case studies are selected for numerical model analysis. In the first case study, the basement-level column C6 and B6 are immediately targeted by the explosive explosion.

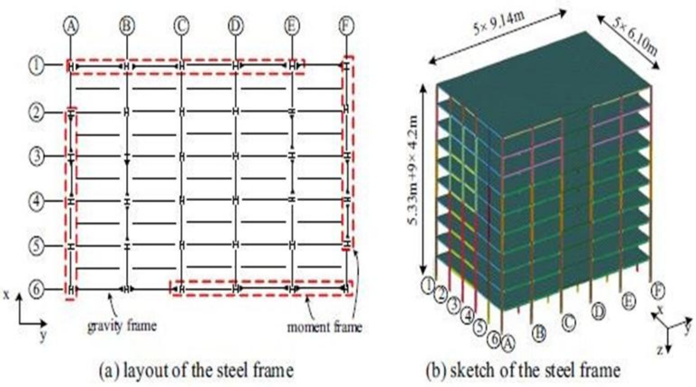


Fig. 1 Layout and sketch of steel frame

2. Progressive Collapse Potential Of A Typical Steel Building Due To Blast Attacks

   Author: H.M.Elsanadedy, T.H. Almusallam, Y.R. Alharbi, Y.A. Al – salloum, H.Abbas

   Journal: Journal of constructional steel research (2014)

This study seeks to analyze the progressive collapse analysis of a typical Riyadh steel-framed 6-story structure to determine its susceptibility to explosion scenarios caused by accidents or terrorist attacks. The building reaction to blast-generated waves was simulated using the commercial FEA programed LS-DYNA. Using the analysis results of a specific structural member subjected to blast load, a numerical model was validated. In this study, two different types of structures—those without a façade wall and those with a facade wall—are taken into account.

The standoff distance of the blast must be greater than 2 m in order to prevent the steel building's potential for progressive collapse. This can be done by limiting vehicle access to the building by perimeter control, which may entail adding security checkpoints and erecting bollards around it.

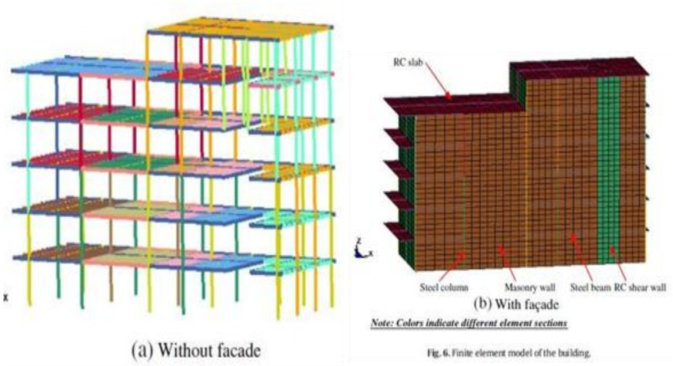


Fig. 2: Elevation of frame building in Riyadh

3. Dynamic Response And Robustness Of Tall Building Under Blast Loading

   Author: Feng Fu

   Journal: Journal of constructional steel research (2012)

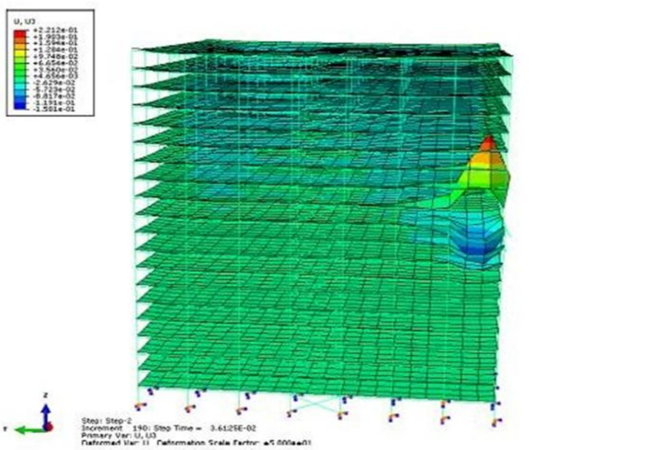
In this research, a 3D numerical model with direct simulation of blast load is proposed to analyze the true behavior of a 20-story tall building under blast loading. In this paper, a typical package bomb charge of 15 kg was detonated on the 12th floor at column A1. Comparisons are made between the outcomes of the ABAQUS, ATBLAST, and APM (alternative path approach from the GSA guideline).

Under the program ABAQUS, the response of structures is governed by the nonlinear dynamic analysis method. The load is computed as DL + 0.25LL in accordance with GSA guidelines. Another exact replica of the model was also constructed in order to compare the outcomes with the alternative path approach. This model used the APM for the analysis. In the analysis, the column A1 on level 12 was suddenly removed at the same location as its counterpart. The structure's response was captured.

The shear check should be provided since the APM technique overlooks the shear force caused by the blast effect on the column. The package bomb only damages specific structural members locally. Also it is hard to trigger the whole building. By enhancing the column shear capacity and increasing its ductility, it can be avoided.

Table 1: Comparison between APM and method from this paper is shown in following table

	Method of this paper	**Alternative path method**
Sheer force of beam B1- A1 at level 13	91 KN	7.9KN
Moment of beam B1-A1 at level 13	100 KN m	27KNm
Compressive force of column B1 at level 12	1460 KN	1700KN
Shear force of column at level 12	220 KN	35 KN



a. Isotropic view (blast detonated at level 12, deformation is amplified)

Fig. 3: View of damaged building

4. Distributed Column Damage Effect On Progressive Collapse Vulnerability In Steel Building Exposed To An External Blast Event

   Author: Jenny Sideri, Chris Mullen, Simos Gerasimidis, George Deodatis

Journal: Journal of performance of constructed facilities (2017)

In order to examine the response and damage to frame members along the building exterior facing an external blast, the purpose of this paper is to investigate a detailed 3D nonlinear finite element dynamic analysis of a steel frame building. In this work, three case studies of steel buildings with distinct structural systems are studied.

The first one is prior to comparing the outcomes with individual single degree of freedom (SDOF) column responses obtained from an analytical approach, a high-rise 20-story building is first subjected to a blast load scenario. A second typical midrise (10-story) office steel building with perimeter moment resisting framing (MRF) is considered. A third typical midrise (10-story) office steel building with inside reinforced concrete and a stiff core is examined.

- Step-by-step simulation of a blast:

1. The application of vertical loads to the structure is the initial phase in the study. These loads are calculated using the load combination of 1.2 DL + 0.5LL (DOD guideline 2009 for progressive collapse analysis).
2. It serves as a transition step between the application of a vertical load and the blast event to ensure that the structure is in a stable condition prior to the blast loading.
3. The actual blast loading process is the third analytical step. This technique of study suggests a total period of 5 s, which is sufficient for vibration to dissipate and adequately record the evolution of structure reaction. This process has two outcomes: either the structure reaches a steady and stable condition or it collapses.
4. Further vertical load is added if the structure manages to survive the bomb scenario of step 3, and it increases until the program does not display a warning of structural failure. The final load that causes collapse is calculated as 1.2DL+0.5LL from step 1 plus an additional vertical load from step 4.

To ensure the system's structural integrity once the blast attack has ended, the bigger column section of the building with the perimeter moment-resisting frames serves as a safety valve. When a structure has an interior RC stiff core, the external columns are unable to stabilize the reaction of the entire system, and a complete collapse is inevitable.

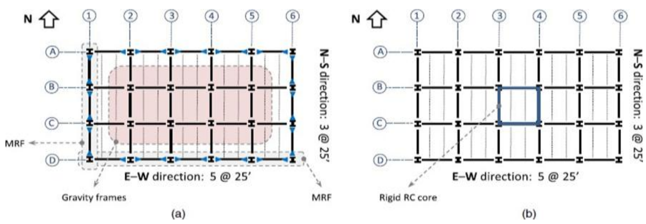


Fig. 4: Plan of the building

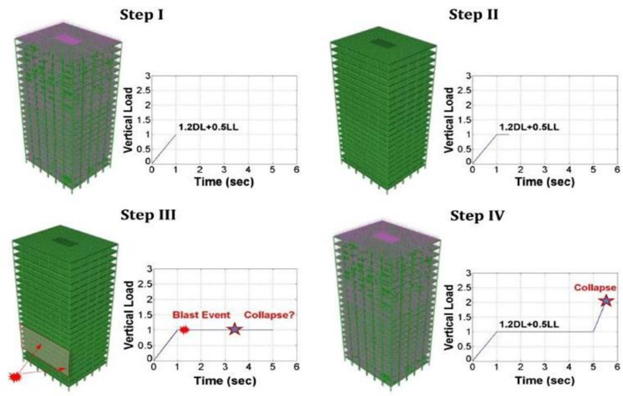


Fig. 5: Simulation of blast event

5. Progressive Collapse Analysis Of A Steel Frame Subjected To Confined Explosion And Post Explosion

   Author: Yang Ding, Ye Chan, Yanchao Shi

   Journal: Advances in structural engineering (2016).

This article provides a precise analytical model for assessing how a steel building that had been subject to a restricted explosion and post-explosion fire gradually collapsed. To precisely analyze the impact of blast-induced damage on the fire resistance of steel structures, the internal blast load is calculated using the finite element program AUTODYN. The USA's National Institute of Standards and Technology (NIST) designed a steel-framed, ten-story structure that was utilized for the progressive collapse analysis. The FEA package LS-DYNA was used to construct the numerical model. A small-span composite steel building was simulated as part of an experimental program to verify the accuracy of the numerical analytical model.

The progressive collapse analysis was performed using a steel-framed structure created by the National Institute of Standards and Technology (NIST) of the USA. The structure is a 10-story office building with a 45.7m x 30.5m layout. 9.14 m by 6.10 m is the usual compartment dimension. Due to the building's seismic category D design, a unique moment structure is used to withstand lateral loads. With the use of 22 mm bolts, A325 high strength bolts, and 9.5 mm A36 shear tabs, the gravity beam and gravity column are joined together by a shear tab connection. Moment frame uses a reduced beam section (RBS) connection with a 50% smaller RBS flange. The composite floor is made up of a 76 mm-deep steel deck and a lightweight RC slab with an 82.5 mm thickness.

Three cases analyses of progressive collapse are taken into consideration: (1) Inner compartment: 216 kg of charge (2) Peripheral compartment case, 196 kg of charge weight (3) Corner compartment case: 216 kg of charge weight.

This article comes to the following conclusion: The membrane action of the floor resists progressive collapse. When the floor's continuity is disrupted, as in the case of an inner compartment under multiple hazards, or when the floor's restraint condition is compromised, as in the case of peripheral and corner compartments under fire or multiple hazards, collapse occurs.

Failure of the gravity column in the inner and peripheral compartments starts the progressive collapse. When a column in the inner MRF fails in a corner compartment, the progressive collapse is started. In contrast to the periphery and corner examples, the interior compartment scenario does not experience connection problems. The gravity column, which is crucial to structural stability, is most likely to experience buckling failure first. While interior MRF columns represent the weakest link of the building, it is advised that MRF columns be placed at external columns. Better resistance to progressive collapse is provided by the shear tab connection's increased toughness. The corner compartment is subject to a combined hazard scenario, whereas the peripheral compartment, which is only subject to a fire case, is the weakest location in a steel building.

3. NEED FOR STUDY, OBJECTIVES OF WORK AND SCOPE OF WORK

3.1 NEED FOR STUDY

Recent technology and computational tools have empowered chemists, physicists, blast consultants, and structural engineers and improved the accuracy of their analyses and the effectiveness of their designs. Also, the demand has grown. In an effort to address the growing concern from a wider group of clients who fear an exposure that they did not anticipate in the past and frequently did not bring upon themselves, a larger group of architects, engineers, blast consultants, and security consultants have joined the small contingent of designers skilled in the art and science of creating structural designs that will resist explosive forces.

Risk assessment, risk reduction programs, security systems, threat design bases, calculating explosion pressures and impulses, and cost-effective structural design are all tasks that are being thrown at consultants who have never had to do them before. Many people lack the skills to react.

Not only for government and military buildings, but also for other high-risk buildings like hospitals, banks, and global commercial headquarters, the blast design of structures has grown in importance. The structure and neighboring structures sustain significant damage as a result of the high explosion. The detrimental effect can be managed if the structure is adequately designed for this loading.

3.2 Objectives of Work

- To look into how steel buildings with multiple stories react dynamically to both internal and external blast loads.
- In the event that gradual collapse happens, look at the chain mechanism.
- Describe practical ways to lessen the explosion effect.

3.3 Scope of Work

- Using the comparison of lateral displacements and member force support reactions, it will be attempted to compare the structural response of a steel frame under blast load and under no blast load.

- The computer program SAP2000 is used for modelling and analysis.
- The analysis of various structure geometries both with and without blast load is done.
- Followed directive: IS 4991:1968.
- Locating the anticipated collapse area.
- It will be attempted to use conventional techniques to identify the required treatments.

4. METHODOLOGY

For the study of the blast loading effect, the finite element method is to be adopted. A common technique for numerically resolving differential equations that appear in engineering and mathematical modelling is the finite element method (FEM). The classic domains of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential are among the issue areas of interest.

Using two or three spatial variables, the FEM is a general numerical method for solving partial differential equations (i.e., some boundary value problems). The FEM breaks down a complex system into smaller, more manageable pieces known as finite elements in order to solve an issue. The numerical domain for the solution, which has a finite number of points, is implemented by creating a mesh of the object using a specific space discretization in the space dimensions.

In the end, a set of algebraic equations emerges from the formulation of a boundary value problem using the finite element method. The technique makes domain-wide approximations of the unknown function. The small system of equations that describes these finite elements is then combined with other equations to model the full issue. The calculus of variations is used by the FEM to minimize an associated error function and then approximate a solution.

5. CONCLUSION

A reliability analysis of steel frame structures against blast loads is presented in this paper. The SS method and a two-step progressive collapse evaluation approach are combined in the risk assessment framework. An enhanced Markov model is added into the SS technique.

The efficiency of calculating the failure probability of uncommon events is improved by the Chain Monte Carlo algorithm. As a deterministic analysis, the two-step collapse evaluation approach is used to determine whether the sample points fall within the failure region. By adding damage severity and responses of individual structural components into structural numerical models in collapse evaluation, it takes the impact of blast load scenarios into consideration. With regard to various VBIED scenarios, blast reliability curves for ten-story steel frame structures are developed.

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