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ANALYSIS OF ELASTIC MULTI-STOREYED STRUCTURE SUBJECT TO BLAST LOADING

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Abstract: The possible catastrophic consequences of blast loading on multi-story buildings have drawn considerable attention in the field of structural engineering. An extensive assessment of studies conducted to examine how elastic multi-story buildings react to blast loading scenarios is summarized in this abstract. The review covers a wide range of topics, such as the properties of blast loading, the dynamic response of structures, the behavior of materials under extreme loading circumstances, and techniques for assessing structural integrity. It looks at how several factors, like the shape of the building, the characteristics of the materials, the strength of the blast, and the distance from the blast source, affect the structural reaction. Additionally, the abstract examines cutting-edge analytical methods, experimental designs, and numerical modelling techniques used to simulate and forecast the behavior of multi-story buildings under blast loading. It also covers developments in retrofitting methods and mitigation tactics meant to increase the blast resilience of these kinds of structures.

I. INTRODUCTION

The susceptibility of structures to blast loading, especially in urban settings, has emerged as a crucial issue in security and structural engineering. Because of their height, complexity, and density of occupants, multi-story buildings, out of all the different types of structures, make up a large amount of urban infrastructure and are especially vulnerable to the consequences of blast events. For the purpose of guaranteeing public safety and infrastructure resilience, it is crucial to comprehend the dynamic reaction of elastic multi-story buildings subjected to blast loading. Attacks by terrorists, industrial mishaps, or unintentional explosions are some of the events that might cause blast loading on structures. Each of these events presents a different set of difficulties depending on the intensity, length, and closeness to the structure. In order to reduce the related dangers, careful study and design considerations are required. The dynamic interaction between the blast wave and the structure causes complex structural responses involving transitory deformations, vibrations, and probable collapse processes. A large amount of research has been focused on understanding how multi-story buildings behave under blast loading circumstances in recent years. The development of analytical models, numerical simulations, and experimental techniques has been the goal of these efforts in order to precisely anticipate and measure the structural reaction. These initiatives have not only increased our knowledge of the interaction between blast and structure, but they have also made it easier to create design principles and mitigation plans that would strengthen a structure's resistance to blast effects. Anagnostopoulos (1988**)** idealized each building as a bilinear force-deformation inelastic structure with a single degree of freedom (SDOF). The results show that the effect of hammering diminishes as the separation grows. Nasarkhaki et al. (2013) conducted numerical research on the pounding between close buildings with different masses during seismic excitation. Jeong-Hun Wonet al. (2015) investigated the impacts of earthquake-induced pounding on bridge piers by analyzing the dynamic responses of a three-span simply supported steel girder bridge. Li-Xiang He et al. (2016) carried out an experimental examination, accounting for spatially varying ground vibrations, on the pounding reactions of neighboring bridge structures using a shaking table. A 2017 study by Guenidi et al. investigated the effects of shared tuned mass dampers on nearby structures. Peizhen Li et al. (2017) studied the phenomena of structure-soil-structure interaction (SSSI) under seismic loads using a three-dimensional finite element numerical simulation with ANSYS software. The lumped mass model is frequently used in seismic pounding research in order to improve understanding of the macro-behavior of structures and to make it easier to build straightforward approaches for resolving this problem (Mate et al., 2017). Nan Jin and Yong-Qiang Yang (2018) examined the impact of pounding and earthquake features on the optimal parameters for an anti-collision system using the time history assessment approach. Mostafa Masoudi and Mona Ghalehnoee (2018) evaluated the seismic performance of base-isolated buildings based on insufficient seismic gaps. To properly calculate the minimal separation gap, Khatami et al. (2019) looked at the periods of two linear and nonlinear buildings that were closely spaced from one another. A study by K Dada Hayat (2021) found that as the structure period increases, so do the maximal hammering pressures. As the separation distance decreases, the collision effect gets stronger. Marco Fouad et al. (2021) provide a method for numerical modelling and non-linear dynamic analysis of RC columns and slab-column buildings subjected to blast loads. Beshoy Mosa et al.'s study (2022) shows how the nonlinear viscoelastic model in this study's Mat-Lab code was able to create pounding between a series of three nearby structures with different natural frequencies.

II. PHENOMENA OF BLAST LOAD AND INTERACTION

Massive amounts of hot gases are released during a blast, compressing the surrounding gases and propelling them farther and faster away from the blast source. The standoff distance is the length of time between the blast source point and the structure. The pressure or intensity of the blast wave continues to decrease as it moves away from the blast source, which has the effect of reducing the effect on buildings with greater standoff distances and shortening the time needed to reach them. The blast wave propagation curves based on pressure and distance from the explosion or blast source are displayed in Fig. 1.

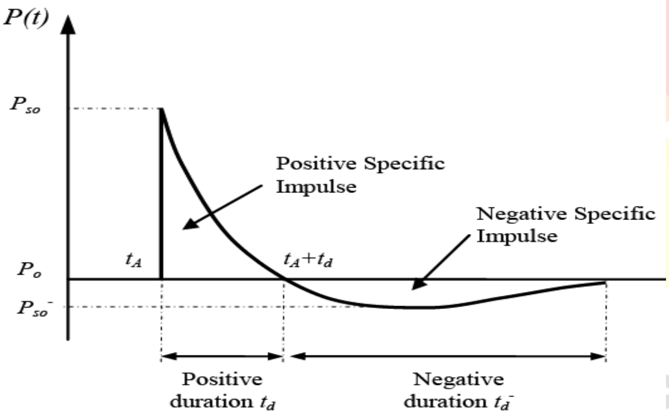

Fig. 1:- Propagation of blast wave

Building reaction to explosive occurrences is largely dependent on blast wave phenomena and how they interact with structures. When an explosion occurs, a high-pressure shock front and a lower-pressure area known as the blast wind follow, causing blast waves to be released abruptly. Complex physical processes interact with these waves and structures, affecting the structural response in a major way. The phenomena of blast waves and how they interact are broken down as follows:

1] Shockwave formation: Rapid energy release during an explosion produces a shockwave, which is characterized by a sharp rise in temperature and pressure. The surrounding air molecules are compressed as this shockwave travels at supersonic speeds outward from the explosion site, creating a front of tremendous pressure.

2] Blast Overpressure: Structures along its path experience an abrupt increase in pressure from the shockwave's leading edge, also referred to as the blast overpressure wave. Depending on the blast's intensity and the structure's closeness to the explosion, this overpressure can result in considerable structural damage, such as rupture, displacement, and fragmentation.

3] Positive Phase Duration: The shockwave's leading edge, also known as the blast overpressure wave, causes a rapid increase in pressure on structures in its path. Significant structural damage, including rupture, displacement, and fragmentation, may arise from this overpressure, depending on the blast's severity and the structure's proximity to the explosion.

4] Negative Phase: The blast wave enters a negative phase, which is marked by a lower pressure region, after the positive phase. When suction forces apply on a structure due to negative pressure, it can lead to further damage or structural failure, especially in light-weight or weakly secured components.

5] Reflection and Transmission: Depending on the shape and material characteristics of the structure, the blast wave experiences diffraction, transmission, and reflection when it comes into contact with it. Complex pressure distributions and loading patterns within the structure can result from these interactions, which can also mitigate or intensify the blast effects.

6] Structural Response: Numerous reactions are triggered by the dynamic interplay between the blast wave and the structure, such as shear forces, flexural deformations, and localized damage. The deformation of structural elements can take several forms, such as bending, buckling, or plastic deformation, contingent on their damping, stiffness, and strength attributes.

III. METHODOLOGY

3.1 Pushover Analysis

Pushover analysis is a simplified analysis technique used to calculate the displacement demand imposed on a building that is predicted to deform inelastically. The link between base shear (Vb) and roof displacement (Δ) is developed. In this study, pushover analysis—a method for obtaining information from structural response under monotonic loading—is used to evaluate the seismic damage of the regular structure. An accumulative dissipated energy function is utilized to assess the state of damage in a high-rise concrete observation structure. The capacity curve is used to determine the structure's damage state at any displacement. A damage scale is suggested to represent the state of the structure's damage at each displacement. The damage scale becomes normal at the ultimate displacement, which is one. The damage scale at any particular displacement is determined by dividing the total energy degraded during the pushover analysis by the ratio of the energy dissipated up to that displacement, excluding the energy wasted as a result of the yield displacement.

3.2 Time History Analysis

Since it is exceedingly difficult to consider a non-linear inelastic building in three dimensions, the actual three-dimensional building is turned into a one-dimensional inelastic stick system made of elasto-plastic. This provides the time history displacement plot and the storey-wise hysteresis plot with great ease. This might be applied to the Excel format calculation of the damage indices.

Modified Park and Ang model represented by the equation 1 is used to get the structural damage index for four ground motions.

$D = X_m - X_y + \beta \int dE$ (1)

$X_u - X_y \quad Q_y X_u$

The parameters in the damage model are as follows: dE is the total cumulative energy dissipated in the hysteresis where the damage should be calculated; Qy is the structure's yield strength corresponding to the yield displacement; Xm is the maximum displacement of each cycle of the hysteresis; Xy is the structure's yield displacement; Xu is the ultimate displacement of the structure under monotonic loading; the value of β depends on the characteristics of the earthquakes; for the present study, its value is taken as 0.4.

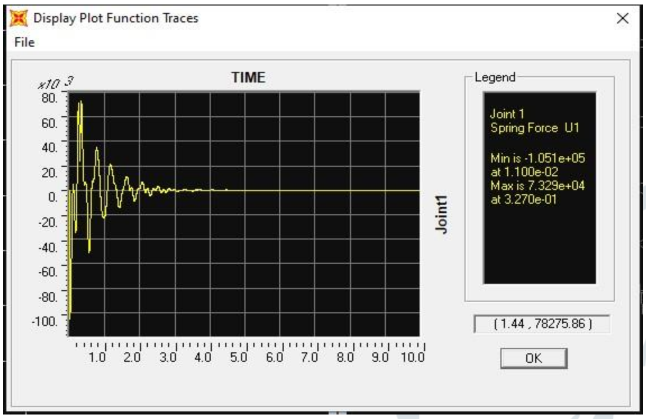

Fig 2: Base Shear of left building

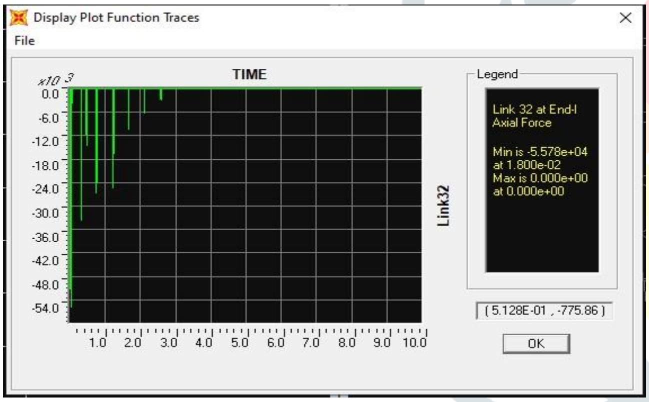

Fig 3: Pounding between structures

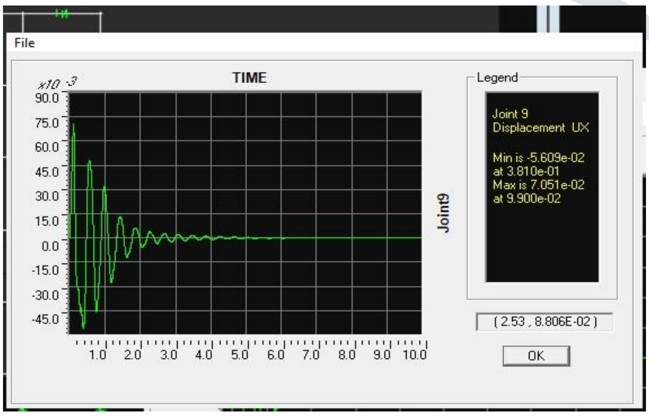

Fig 4: Top Displacement of left building

IV. Conclusion:

- ➢ The results obtained from the buildings subjected to blast load with different standoff distances and charge weights indicate that when the blast source point is far away from the building's front face base shear, pounding and top displacement are observed less.
- ➢ When the standoff distance and blast charge weight are less, the building responds more in terms of pounding and displacement. As a result, the response can be expressed as being inversely proportional to the charge weight and standoff distance.
- ➢ The building's safe standoff distance is considered as the distance that have minimum impact of blast on building.
- ➢ Compared to bare frame buildings, the installation of a tuned mass dampers at the top of left building reduces storey displacement and drift by 49.43%.
- ➢ By installing steel mass dampers at the building's bottom periphery, storey displacement is reduced by 23%, when compared to bare frame buildings.
- ➢ As a result, the building is more resistant to blast loads when tuned mass dampers and steel bracings are installed.

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