Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 4, No. 7, April : 2024

DYNAMIC ANALYSIS OF RC BUILDING UNDER BLAST LOAD USING IS4991

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Abstract
Due to the growing worldwide dread of conflict, there has been a surge in demand for blast-resistant design for important facilities such as hospitals, government buildings, etc. An explosion causes a structure to experience extraordinarily high pressure for a brief period of time, which means that the building is subject to extremely harsh impact and may sustain major structural damage. Important structures must be constructed such they can bear those high loads without experiencing any significant collapses. The procedures described in IS 4991 are used to estimate blast loads. Based on the distance from the blast source, the pressure intensity from IS 4991 has been computed and converted to point loads acting at each level. In order to improve the building's performance, response spectrum analysis is carried out for seismic loading in addition to blast loads. Variables such maximum lateral displacement, maximum story drift ratio, time period, maximum over-turning moment, etc. are compared. In order to quantify the impact of blast loads at different standoff distances and intensities, the intensity of the blast load has also been altered. The project's anticipated results include understanding the impact of unintentional blast loading at a certain distance from the building and, following analysis of the aforementioned cases, recommendations for mitigating the effects of blast loads, such as the addition of shear walls and composite steel-RCC columns. The structural study is carried out using ETABS, a finite element program.
Key Words: Blast load, IS4991, ETABS, TNT, Standoff distance

I. Introduction
Explosions resulting from a variety of causes, including acts of terrorism, gas leaks, nuclear explosions, industrial facility accidents, and thermal power plants, apply blast forces to buildings, creating a new danger to structures that were originally intended to support static loads. Destructive events such as the Oklahoma City, USA, vehicle bombing of the Murrah Federal Building in 1995 and the New York World Trade Center bombing in 1993 have highlighted the significance of carrying out thorough investigations to comprehend how structures function under blast loading. Because blast forces are dynamic in nature, they should be taken into account in design just like earthquake and wind loads. To protect both building inhabitants and the buildings themselves, it is imperative to design structures that can withstand blast loads. An in-depth examination of blast phenomena and their impact on various structural components is essential for the analysis of buildings exposed to these kinds of stresses.
Often referred to as hardened structures or blast-resistant buildings, these constructions are made to withstand the effects of explosive blasts, such as those brought on by terrorist attacks or unintentional industrial explosions. During such catastrophic events, these structures use sophisticated engineering and construction procedures to minimize damage and safeguard people.
It takes a collaborative, multidisciplinary approach involving professionals from architecture, structural engineering, materials science, and security measures to design and build blast-resistant structures. The main goal is to design structures that can effectively protect people and essential infrastructure in the case of possible bomb occurrences. Modern blast-resistant design ideas are incorporated into these structures with the goal of improving everyone's overall safety and security. To ensure optimal performance during severe events, a holistic evaluation of numerous elements is necessary due to the complexity of the task. These structures are constructed to withstand and lessen

the impact of blast forces, minimizing possible damage and providing a secure environment for people and vital operations thanks to the combined experience of varied professionals. The global commitment to safeguarding communities and defending vital assets against unforeseen dangers is exemplified by the creation of buildings that are resistant to blasts.

II. Literature

Shi, Y., Sun, X., & Cui, J. (2023**)** examined the durability of columns made of reinforced concrete under the combined influence of blast and seismic loads. This study filled a vital gap in the field of structural engineering, where building resilient structures is made more difficult by the interactions between blast loads and seismic occurrences. In order to evaluate the performance of reinforced concrete columns under combined loading conditions, the authors carried out a thorough reliability investigation. The study offers insights into the possible weaknesses and strengths of certain structural elements by incorporating blast and seismic effects. By providing a mathematical understanding of the combined effects of seismic and blast loads, the research made a substantial contribution to the field and improved the capacity to design structures that can endure numerous extreme events. For engineers and designers working on complicated loading situations structures, their findings have practical consequences. The research contributes to the optimization of construction methods and fortification of key infrastructure against unforeseen difficulties by evaluating the reliability of reinforced concrete columns in these types of scenarios. In summary, their research makes a significant contribution to our knowledge of how structures behave under combined blast and seismic pressures, which will help us design more resilient built environments.

R. G., Anas et. al. (2023) carried out a thorough investigation into blast loading and the underlying mechanics. The review clarifies the nuances of blast wave creation, propagation, and interaction with different structures by compiling and integrating a wealth of research. Important ideas are thoroughly examined, including shock waves, positive and negative pressures, and the impact of impulse. The paper emphasizes how crucial it is to understand blast dynamics in order to improve masonry structures' resistance to these kinds of catastrophic occurrences. The review highlights the need for precise numerical models and experimental validations in evaluating blast effects on infrastructure and buildings by critically analyzing current developments. This synthesis is a useful tool for professionals involved in building strong structures and putting in place efficient explosion prevention measures, as well as researchers looking for a current grasp of blast dynamics. To conclude, this review of the literature adds a great deal to the body of knowledge by bringing together recent study findings, pointing out areas of present understanding that need to be filled, and outlining potential pathways for future research. It is a vital resource for the domains of blast engineering and structural resilience due to its thoroughness and insights.

Cui, L., Zhang, X., Hao, H., & Kong, Q. (2022**)** marked a substantial breakthrough in our understanding of how reinforced concrete (RC) elements react to loads. By putting forth improved resistance functions that take into account both compressive and tensile membrane activities, the authors addressed a crucial component of RC structural behavior. This new method recognizes how these processes interact in complex ways that have an impact on the overall performance of the structure at different loads. Through the integration of this complementary factor, the research enhanced the precision of forecasting models and their usefulness in engineering design and analysis. The research explores the subtleties of the behavior of RC elements using a multidisciplinary approach that combines mechanical and civil engineering, offering important insights for boosting their resilience. The results of this work have applications in the construction of more robust and effective structures, especially in situations where complex and dynamic loading conditions are present. Through the integration of theoretical analysis and practical applications, the writers facilitate the continuous advancement of structural engineering methodologies.

Rizwanullah, & Sharma, H. K. (2022**)** carried out a thorough investigation of how blast loading affects structural elements made of Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC). The study tackled a crucial issue for civil engineers since the resilience of infrastructure and public safety are greatly impacted by a structure's susceptibility to explosive events. The authors conducted a comprehensive literature review to explore the complex dynamics of UHPFRC components during blast stress. The review carefully investigated how these advanced concrete materials were affected by shock waves, high pressures, and impulse forces. They offered a thorough summary of the behavior of UHPFRC structural elements under blast conditions by combining the results of several investigations, pointing out advantages, disadvantages, and possible directions for future investigation. By illuminating UHPFRC's performance under extreme situations, such explosions, this review made a substantial contribution to the corpus of developing information. The knowledge gained from this study will have a significant impact on how structures that must survive blast loading are designed and built, increasing their longevity and safety.
Ahmed Galal, et. al. (2020) examined how a severe blast load affected the progressive collapse behavior of a sophisticated steel-concrete composite building. This study evaluated a structure's resistance to cascade failures brought on by abrupt and intense occurrences, which is an important component of structural engineering. The authors examine the complex physics of progressive collapse in a three-dimensional composite building under blast loads through a thorough investigation. Through an examination of how the interplay between steel and concrete constituent's impacts the robustness of the structure, the research offers significant perspectives for the design of resilient buildings that can resist unforeseen circumstances. The study made a substantial contribution to the discipline by improving our knowledge of the mechanisms underlying gradual collapse in complex composite structures. The results of this study have practical consequences for engineering methods. Specifically, they can help design strategies to limit or prevent failure from spreading during catastrophic events.
Megha, S. M., & Ramya, K. (2019) examined the behavior and dynamic response of reinforced concrete structures under blast events; this was an important field of study because of the possible effects of such pressures on occupant safety and building integrity. The authors investigated the numerous facets of blast load analysis on multi-story RC buildings by means of a thorough survey of the body of current research. This entails the assessment of structural reaction characteristics like displacement, acceleration, and stresses in addition to the selection of suitable blast load time histories and numerical modeling methodologies. The review also looks at how various design elements, like material compositions, structural layouts, and reinforcing specifics, affect how well reinforced concrete buildings function in blast environments.
Elsanadedy, H. M., et. al. (2014) examined the possibility of steel buildings collapsing gradually in the event of an explosion attack, a crucial issue for structural security and safety. It examined how steel buildings behave structurally when subjected to blast loads, emphasizing the need of comprehending the dynamic behavior and localized damage effects. Numerical simulations and vulnerability assessments are probably used in the research to see how the building reacts to loads caused by blasts. In an effort to strengthen building resilience and stop the spread of progressive collapse, blast-resistant design techniques and mitigation methods are investigated. The review also has a strong emphasis on real-world case studies, which offer insightful information about how steel structures behave in genuine blast situations.

1.1 Explosion and blast phenomenon

A blast is the result of an extremely large amount of energy being released suddenly from a source for very brief periods of time (few milliseconds to microseconds). The structure is damaged by the vibrating waves that a blast causes. Hot gasses with a temperature of around 3000-40,000 C and a pressure of up to 30×108 Pascal are produced when a condensed high explosive detonates [Ngo et al., 2007]. A pressure wave is produced when a charge explodes in a building's outside area, which causes an impulsive stress on the structure. The wave travels in roughly spherical wave fronts from the source

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 4, No. 7, April : 2024

point and is reflected when it collides with the wave front. The blast wave's duration lengthens, velocity drops, and power diminishes as it expands. For simplicity's sake, blast load is typically thought of as a triangular load that decays linearly. The application of blast loads is similar to that of wind loads; the only distinction is that blasting is a sudden, high-load, brief activity. Based on their nature, explosions can be classified as chemical, nuclear, or physical occurrences.

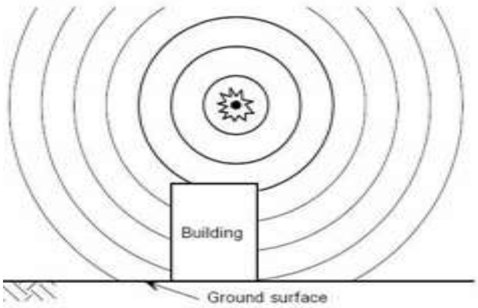
Physical explosion: Volcanic eruptions, the breakdown of a compressed gas cylinder, or the mixing of two liquids at different temperatures can all release energy.

Nuclear explosion: The redistribution of protons and neutrons within the inner acting nuclei releases energy from the production of distinct atomic nuclei.

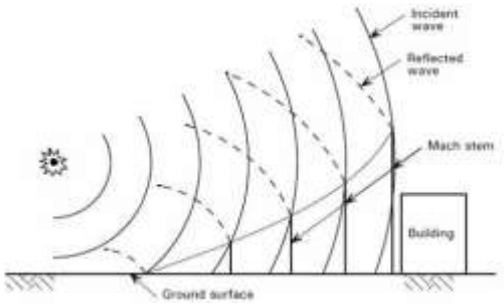
Chemical explosion: The rapid oxidation of the fuel elements (carbon and hydrogen atoms) is the main source of energy.

1.2 Types of explosion

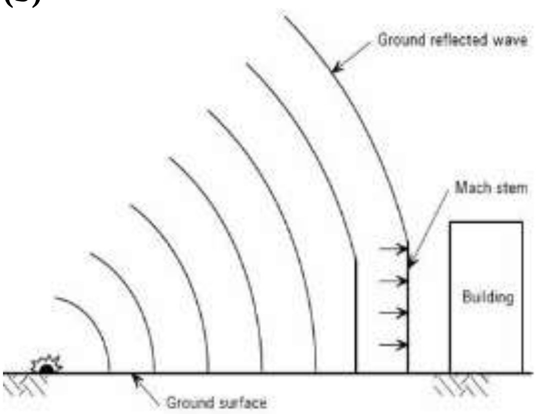
Based on how the explosive is contained, such as confined or unconfined explosion, blast loads on structures can be split into two major categories.



(a)



(b)



(b)

Fig. 1: (a) Free air burst explosion **(b)** air burst explosion (c) Surface burst explosion

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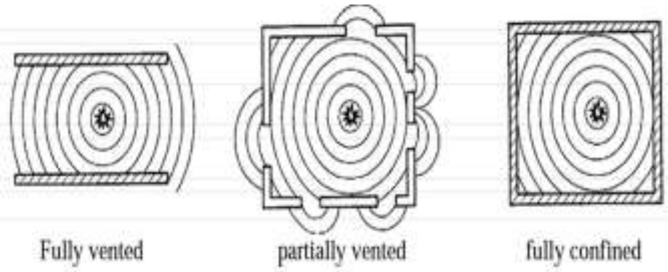

Fig. 2: Confined explosions

2. METHODOLOGY

The blast load depends upon two major factors defined by the bomb size or charge weight W, and the standoff distance (R) between the blast source and the target.

Think about the structures exposed to a detonation at a specific standoff distance that would yield some kg of TNT. The most practical way to depict the blast effects in a dynamic structural analysis is to apply a loading-time history to the structural members as transient loading. Table 1 from IS 4991-1968 is used to calculate the blast load's magnitude and pressure-time history. The front face is divided into several clearly defined grids, and the total impulse on each grid point is calculated as part of the blast load calculation process. It is reasonable to suppose that every beam-column joint on the front face of the buildings is subject to time-varying triangular forces. These pulses have zero rise time and decay linearly as shown in Figure 3.

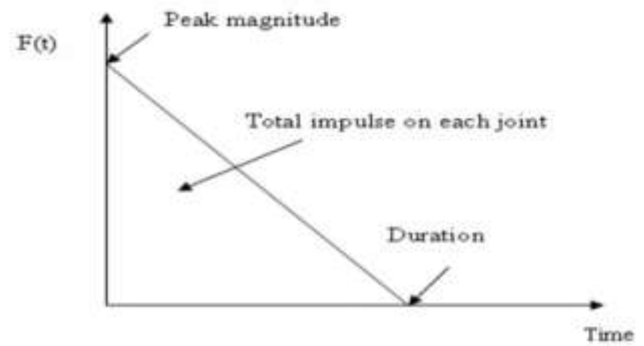

Fig. 3: Blast Loading Function

The blast is directed in the letter X. On the building's front face are the column-beam joints in their entirety. In order to account for the distance between each joint and the explosion source, the forces resulting from blast loading should be applied to the buildings as triangle loading functions that are independently calculated for each joint on the building's front face. To determine the peak load at a beam-column joint, multiply the reflected pressure at each joint by the tributary area. Finding the positive time length also allows us to create the load-time history for every joint, which we can then feed into ETABS. We will receive the building's response in terms of acceleration, velocity, and displacement.

A 26-story RCC building case study project has been taken into consideration in our research. Displacement, velocity, acceleration, time period, and other ground motion data are compared. To compare the effects of blast loads at various standoff distances and intensities, we have also adjusted the blast load intensity. Additionally, after analyzing the aforementioned situations, some solutions will be shown for lowering the effects of blast loads by using building bracings and shear walls. The finite element analysis program ETABS is used to replicate the structural parameters of both R.C.C. buildings. To develop 3D models, analyses, and designs, this is utilized. The software can do nonlinear dynamic analyses, eigen values, and nonlinear static pushover in addition to accepting static loads (forces or displacements) and dynamic actions (accelerations). M30 is the grade of concrete used for

the slab, column, and beam. Steel grade: Fe 500. There is three meters between floors. AAC blocks are used to construct partition walls in order to lessen the structures self-weight.
Following cases are considered for study:
1. 0.1T blast load at 10m standoff distance.0.1T blast
2. load at 20m standoff distance
3. 0.3T blast load at 10m standoff distance
4. 0.3T blast load at 20m standoff distance

After analysing all the above mentioned cases possible retrofit methods for the reduction of blast load effect like introduction of shear walls and steel bracings will be discussed. Overall results will be compared and best suited method will be proposed.

5. 0.1T blast load at 10m standoff distance with shear wall
6. 0.1T blast load at 20m standoff distance with shear wall
7. 0.3T blast load at 10m standoff distance with shear wall
8. 0.3T blast load at 20m standoff distance with shear wall
9. 0.1T blast load at 10m standoff distance with composite column
10. 0.1T blast load at 20m standoff distance with composite column
11. 0.3T blast load at 10m standoff distance with composite column
12. 0.3T blast load at 20m standoff distance with composite column

Fig. 4: Top view of the Building in AutoCAD
ABS

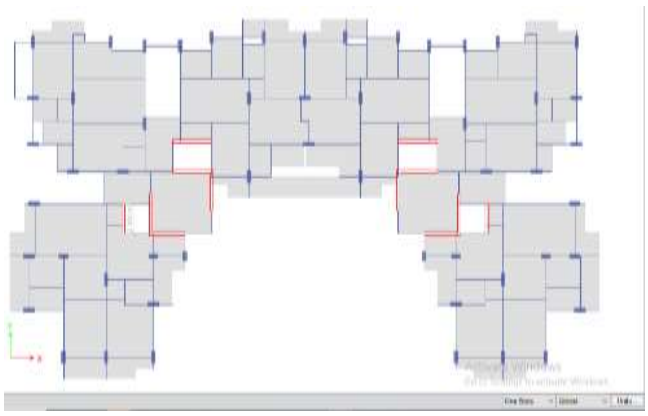

Fig. 5: Top view of the Building in ET

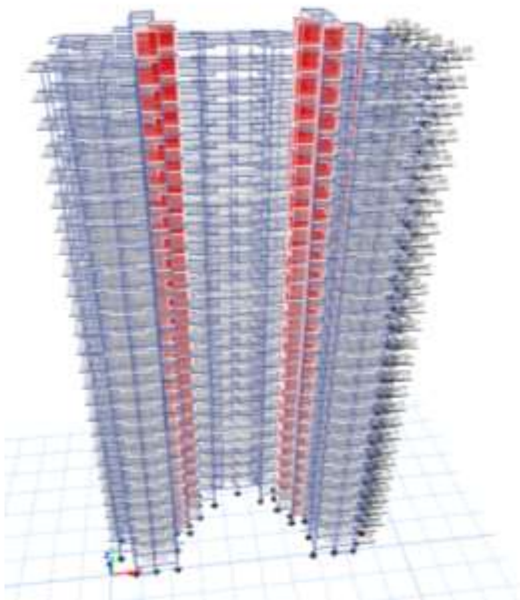

Fig. 6: 3D rendering view of building in ETABS

3. RESULTS AND DISCUSSIONS

IS 4991-1968 is used for blast load calculations. For calculation of peak reflected overpressure for different charge weights and different actual standoff distances we have used the scaling law:

(S) = (X)/W (1/3)

{Clause 5.3 of IS 4991-1968}

[1kg/cm2 = 98.1 kN/m^2]

Here, the maximum impact of blast on any building model is on lowest level i.e. ground floor (GF) & minimum impact on topmost level i.e. terrace (T). The actual Stand-off distances (X*) are calculated by considering origin (0, 0, 0) at the Bottom right corner of the building at GF level. Thereafter, the actual/equivalent scaled distances (S*) are calculated by taking ratio of {X*/X} & multiplying it by scaled distance (S).

The blast peak reflected overpressure (pro) values are converted into blast point loads by multiplying them by the area of the respective joint. Therefore, when loading is applied along the X-axis along the shorter face of the building, the building face (and joints on it) normal to the X-axis are considered for calculations. Loads are not applied as pressure intensity as the considered surface is not uniform and also not aligned.

The values of joint loads are then applied to RCC, RCC with shear walls, and composite building models separately with varying parameters in both ETABS software. The behaviour of the corresponding building models after blast loading is examined using linear static analysis.

It was discovered that the value of story drift in the X and Y directions sharply drops with an increase in standoff distance after analysis was done on all 12 building models in ETABS. Additionally, tale drift increases by more than twice as much when the blast load weight is increased from 0.1T to 0.3T. In addition, tale drift is marginally less in composite columns than in RCC columns. When shear walls are used, there is a significant (20%) decrease in story drift in the X direction (the direction of blast loading). Additionally, it is discovered that as standoff distance rises, the value of maximum lateral displacement in the X and Y axes grows dramatically. Furthermore, there is a more than two-fold increase in the maximum lateral displacement when the blast load weight is increased from 0.1 T to 0.3 T. In addition, the maximum lateral displacement of composite columns is marginally less than that of RCC columns. When shear walls are used, there is a significant, roughly 15-20%, decrease in lateral displacement in the X direction (the direction of blast loading).

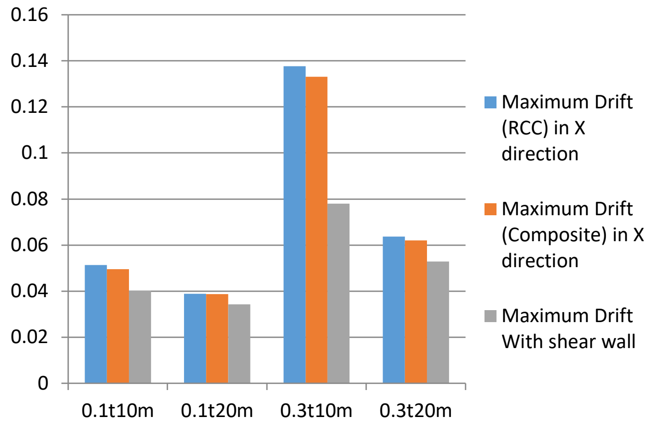

Chart-1: Variation of Story drift in X direction for RCC Columns shear wall and with Composite Columns

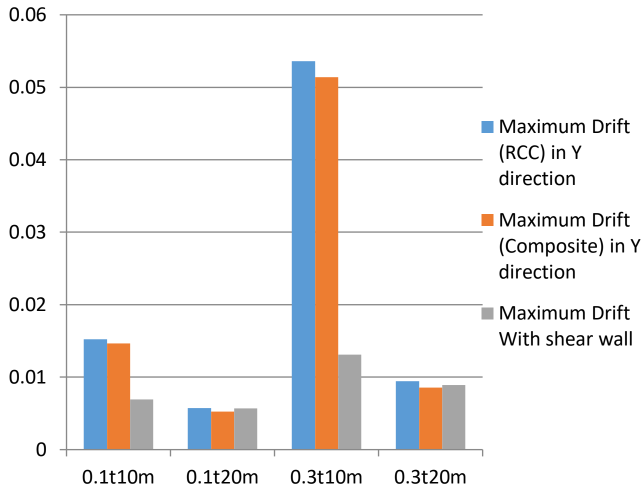

Chart-2: Variation of Story drift in Y direction for RCC Columns shear wall and with Composite Columns

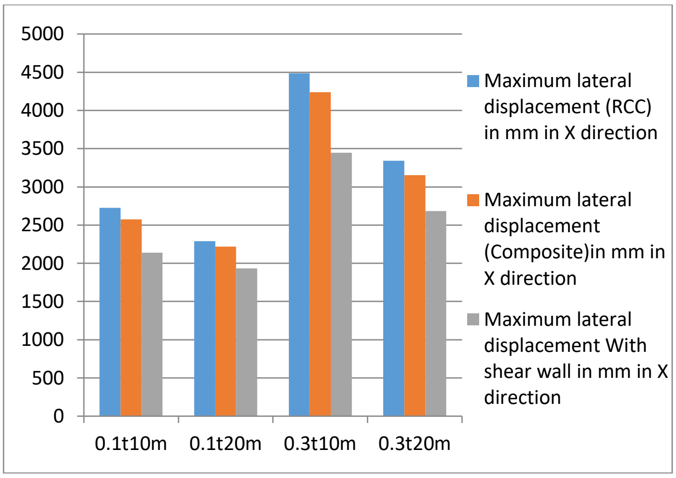

Chart-3: Variation of maximum lateral displacement in X direction for RCC Columns, shear wall and with Composite Columns

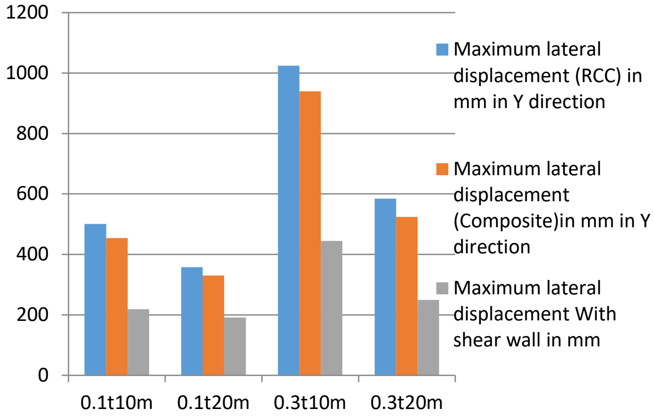

Chart-4: Variation of maximum lateral displacement in Y direction for RCC Columns, shear wall and with Composite Columns

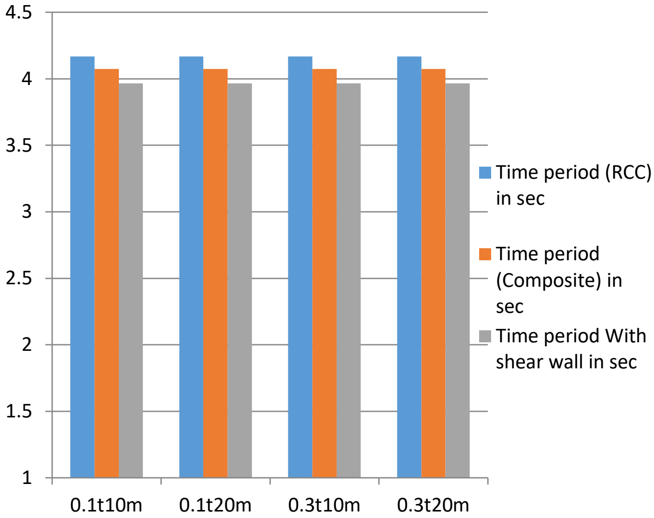

Chart-5: Variation of Time Period RCC Columns, shear wall and with Composite Columns

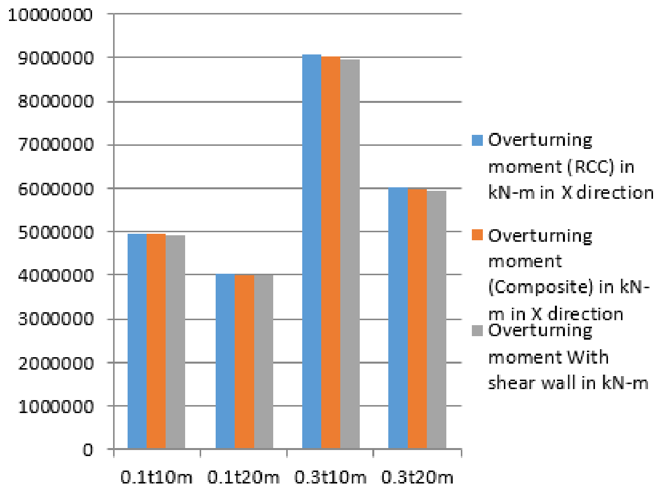

Chart-6: Variation of over-turning moment for RCC Columns, shear wall and with Composite Columns

4. CONCLUSIONS

We can conclude that the value of tale drift in the X and Y directions grows dramatically with an increase in standoff distance after examining all examples with varying blast load intensities and

standoff distances. Additionally, there is a noticeable increase in tale drift as the blast load intensity rises. When shear walls are used, there is a significant (20%) decrease in story drift in the X direction (the direction of blast loading). The results for greatest lateral displacement also resembled tale drift. The building's time period remains very constant throughout a range of explosion and standoff distances. Shear walls result in a comparatively small (3–4%) reduction in the building's construction period. The maximum overturning moment for composite and RCC columns is nearly equal, however it increases by 1.5 times when blast loading rises from 0.1 T to 0.3 T. When shear walls are used, the maximum overturning moment is somewhat decreased—roughly 1% to 2%.
Compared to the composite building, which features steel columns encased in concrete, the RCC construction is more susceptible to explosions. Shear walls can also greatly lessen the impact of blast loading in RCC buildings—roughly by twenty to twenty-five percent. In summary, a high-intensity blast created at a much shorter standoff distance is more likely to cause damage to a multi-story building.

References

[1] Shi, Y., Sun, X., & Cui, J. (2023). Reliability analysis of reinforced concrete columns under combined seismic and blast loads. Science China Technological Sciences, 66(2), 363-377.
[2] Anas, S. M., Alam, M., Umair, M., Saifi, F., Haris, M., Shariq, M., & Kanaan, M. H. G. (2023). Explosions and mechanism of blast loading: a review. International Journal of Masonry Research and Innovation.
[3] Cui, L., Zhang, X., Hao, H., & Kong, Q. (2022). Improved resistance functions for RC elements accounting for compressive and tensile membrane actions. Engineering Structures, 251, 113549.
[4] Rizwanullah, & Sharma, H. K. (2022). Blast loading effects on UHPFRC structural elements: a review. Innovative Infrastructure Solutions, 7(6), 341.
[5] Ahmed Galal, M., Bandyopadhyay, M., & Krishna Banik, A. (2020). Progressive collapse analysis of three-dimensional steel–concrete composite building due to extreme blast load. Journal of Performance of Constructed Facilities, 34(3), 04020021.
[6] Megha, S. M., & Ramya, K. (2019). Analysis of multi-storey RC building subjected to blast load using time history method. International Journal of Innovative Science and Research Technology, 4(6), 556-562.
[7] Elsananadedy, H. M., Almuallam, T. H., Alharbi, Y. R., Al-Salloum, Y. A., & Abbas, H. (2014). Progressive collapse potential of a typical steel building due to blast attacks. Journal of Constructional Steel Research, 101, 143-157.
[8] U.S. Army Corps of Engineers, Naval Facilities Engineering Command, & Air Force Civil Engineer Support Agency. (2008). UFC 3-340-02 Structures to Resist the Effects of Accidental ExplosionsAnand, R.; Karthiga, R.D.; Jeevitha, T.; Mithra, J.L.; Yuvaraj, S. Blockchain-Based Agriculture Assistance. Lect. Notes Electr. Eng. 2021, 700, 477.