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Structural Analysis of Blast Resistant Building with RC Structure Having Shear Wall and Braces

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ABSTRACT: The increase in the number of terrorist attacks especially in the last few years has shown that the effect of blast loads on buildings is a serious matter that should be taken into consideration in the design process. Although these kinds of attacks are exceptional cases, man-made disasters; blast loads are in fact dynamic loads that need to be carefully calculated just like earthquake and wind loads. The objective of this study is to shed light on blast resistant building design theories, the enhancement of building security against the effects of explosives in both architectural and structural design process and the design techniques that should be carried out. Firstly, explosives and explosion types have been explained briefly. In addition, the general aspects of explosion process have been presented to clarify the effects of explosives on buildings.. The research includes information about explosives, blast loading parameters and enhancements for blast resistant building design both with an architectural and structural approach.

KEYWORDS: Blast Resistant structures, Stand-off distance, Blast loading, Scaled distance.

I. INTRODUCTION

Damage to the building causing loss of lives is a factor that has to be minimized if the threat of terrorist activities cannot be stopped. This paper gives guideline measures for overcoming the effects of explosions, hence providing protection to the structures and lives. Ductile elements like steel and RCC can absorb a significant amount of strain energy, whereas brittle elements like PCC, timber, brick masonry, glass, etc. fail abruptly. IS 4991-1968 has failed to deal with the different kinds of loads developed in the dynamic response of a building to bomb blast. They need further explanation as the engineers have no guidance on how to design or evaluate structures for the blast anomaly for which an elaborated understanding is required. Though this topic is of prime importance in the military circles and important data derived from tests and experiments have been restricted to army use only. Yet a number of publications are available in the public domain by the US agencies. In this paper, exploration of the literature on blast loading, explanation of special conditions in defining these loads and also the exploration of the vulnerability assessment and risk management of structures with standard structural analysis software having nonlinear capabilities. [7]

Blast loads cannot and should not be compared to seismic load. Unlike Seismic load, blast loads occur for a very short duration. Thus material strain rate effects become a crucial point that must be considered for defining connection performances in case of blast loads. However, it is not possible to make a building both seismic proof and blast proof at the same time and blast loads are applied on a structure irregularly. Unlike seismic load intensity, blast load intensity is of very magnitude in a particular region or space for a fraction of a second.

Preventive Philosophy

It is not possible to design a building for an equivalent static load. During designing the philosophy that could be followed is (considering that the blast occurs outside the building):

The exterior columns could be considered to be removed from the structural frame and considering the interior most columns having less capacity, so that the section of the interior columns are more than the usual. The load for the missing columns should be distributed by using suitable techniques

After considering that the exterior columns are removed, the beams should be made stronger than the usual, as after the blast, the beams are weak (due to the actual removal of the exterior columns) and hence they distribute the load to the interior columns.

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- Provision of shear walls at suitable intervals.
- Detailing and connections
- Use special seismic moment frame details.
- Avoid splices at plastic hinge locations.
- Provide continuous reinforcing through joints

Structural Form and Internal Layout

Structural form is a parameter that greatly affects the blast loads on the building. Arches and domes are the types of structural forms that reduce the blast effects on the building compared with a cubicle form. The plan-shape of a building also has a significant influence on the magnitude of the blast load it is likely to experience. Complex shapes that cause multiple reflections of the blast wave should be discouraged. Projecting roofs or floors, and buildings that are U-shaped on plan are undesirable for this reason. It should be noted that single story buildings are more blast resistant compared with multi-story buildings if applicable. Partially or fully embed buildings are quite blast resistant. These kinds of structures take the advantage of the shock absorbing property of the soil covered by. The soil provides protection in case of a nuclear explosion as well.



Fig 1 Stand-Off Distances

II. LITERATURE REVIEW

The selected literature collectively emphasizes the critical importance of understanding and designing structures to withstand blast loads due to rising global threats from terrorism and accidental explosions. Figuli et al. (2008) provide a foundational analysis of blast-loaded structures and the parameters essential for dynamic assessment, while **Moinuddin et al. (2018)** demonstrate the effectiveness of bracing in reinforced concrete structures against varying blast intensities. **Unde et al. (2013)** focus on the unpredictable nature of explosions and the need for finite element tools in evaluating structural responses. **Remennikov et al. (2015)** underline the global paradigm shift post-9/11 in engineering practices toward resilient infrastructure. **Kandil et al. (2014)** compare implicit and explicit numerical methods, concluding that explicit modeling more accurately predicts slab behavior under blast loads. **Coffield et al. (2016)** reveal that structural irregularities significantly influence steel frames' responses to blasts, with concentrically braced frames offering better resistance. **Bhatt et al. (2016)** compare blast and earthquake impacts, finding that blast loads cause greater displacement and demand higher material use. **Habib et al. (2021)** show that shear walls effectively mitigate blast-induced displacements and drifts. **Guha et al. (2020)** conduct a parametric study revealing that higher floors show reduced deflection, and **Chudiwal et al. (2020)** stress the economic and safety implications of designing life structures like buildings and dams with blast resistance in mind. Overall, the literature converges on the necessity of incorporating blast load considerations into civil engineering to safeguard infrastructure and lives.





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III. PROBLEM STATEMENT

A RCC high rise building of G+25 stories with floor height 3m subjected to blast loading has been considered .In this regard, ETABS software have been considered as tool to perform. Hence in this chapter we will discuss the parameters defining the computational models, the basic assumptions and the geometry of the selected building considered for this study. Displacements, shear force and bending moment have been calculated for the RC structure having shear wall and the RC Structure having braces.

In this project, a plan of 20 storey building is selected with introduction of blast load, thefollowing 2 cases will be considered:

- Case 1: RC structure having shear wall
- Case 2: RC Structure having braces

The amount of explosion and the loads caused by it cannot be predicted exactly, the most possible scenarios or cases will let to find the required engineering and architectural solutions for it. For this dynamic analysis with design will done on all the cases using ETAB software the comparison of parameter like Storey Displacement, Shear Force, Bending Moment is done with respect to standoff distances in above two cases and also comparison for these two cases.

Sr. No.	Parameter	Values		
1	Number of storey	G+25		
2	Base to plinth	1.5m		
3	Floor height	3.3m		
4	Shear wall	200 mm thick		
5	Materials	Concrete M30 and Reinforcement Fe 500		
6	Frame size	12m X 12m building size		
7	Grid spacing	3m grids in X-direction and 3m grids in Y-direction.		
8	Bracing	ISMC125		
8	Size of column	amn 300 mm x 600 mm		
9	Size of beam	300mm x 550 mm		
10	Depth of slab	150 mm		
11	Total height	87.3 m		
12	Plan area	144 m2		

Table 1 Parameters to be consider for rectangular geometry analysis





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Fig 2 Model 1- G+25 with Shear Wall



Fig 3 Model 2 G+25 with Bracing

IV. RESULTS AND ANALYSIS

Results For Blast Loading SW And Bracing Natural Frequency Hz

Table 2 Natural Frequency Hz

Natural Frequency Hz						
Mode	With Shear Wall	With Bracing				
1	0.448	0.343				
2	0.503	0.397				
3	0.817	0.658				
4	1.636	1.171				
5	1.834	1.433				
6	2.811	2.036				





The table compares the natural frequencies (in Hz) of a structure with shear walls and with bracing across six vibration modes. In all modes, the structure with shear walls exhibits higher natural frequencies than with bracing, indicating that shear walls provide greater stiffness and resistance to dynamic motion. As the mode number increases, the natural





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frequency also increases for both configurations, reflecting higher-order vibration modes. Overall, the presence of shear walls enhances the structural rigidity more effectively than bracing.

Time Period

Table 6.2 Time Period

Time Period						
Mode	with Shear Wall	with Bracing				
1	2.23	2.91				
2	1.98	2.517				
3	1.22	1.52				
4	0.611	0.854				
5	0.545	0.698				
6	0.356	0.49				





The table shows the time periods (in seconds) for different vibration modes of a structure with shear walls and with bracing. In all modes, the structure with bracing has longer time periods than the one with shear walls, indicating it is more flexible and less stiff. Shorter time periods in the shear wall configuration reflect higher stiffness and faster structural response. As the mode number increases, the time period decreases, showing that higher modes correspond to quicker vibrations. Overall, shear walls improve structural stiffness more effectively than bracing





Fig 4 Bracing With Shear Wall







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Fig 6 Shear Wall At Even Floor

Displacement

Table 6.7 Displacement in mm

Displacement in mm						
Storey	with Shear Wall	with Bracing	Bracing With Shear Wall	Shear Wall at odd and even floor		
27	70.02	138.664	55.495	66.255		
26	67.913	134.132	53.339	63.802		
25	65.774	129.478	51.152	61.223		
24	63.567	124.685	48.938	58.76		
23	61.279	119.754	46.69	55.999		
22	58.901	114.683	44.407	53.531		
21	56.426	109.477	42.088	50.602		
20	53.852	104.139	39.736	48.143		
19	51.178	98.679	37.352	45.064		
18	48.406	93.104	34.941	42.634		
17	45.537	87.426	32.508	39.428		
16	42.579	81.658	30.058	37.054		
15	39.536	75.815	27.598	33.751		
14	36.418	69.913	25.138	31.466		
13	33.235	63.97	22.686	28.102		
12	30.001	58.007	20.252	25.944		
11	26.73	52.045	17.849	22.56		
10	23.444	46.111	15.489	20.574		
9	20.165	40.231	13.19	17.218		
8	16.924	34.437	10.968	15.456		
7	13.757	28.765	8.844	12.183		
6	10.712	23.256	6.845	10.703		
5	7.849	17.959	5.001	7.574		
4	5.245	12.933	3.351	6.441		
3	2.998	8.25	1.945	3.522		
2	1.24	4.012	0.851	2.816		
1	0.168	0.583	0.144	0.107		
0	0	0	0	0		





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Graph 6.7 Displacements in mm

The displacement data (in mm) across storeys shows the lateral movement of a structure under four different configurations: with shear wall, with bracing, with both bracing and shear wall, and with shear wall at odd and even floors. The bracing-only configuration consistently has the highest displacements, indicating the least stiffness, while the combination of bracing with shear wall results in the lowest displacements, showing the highest stiffness and best control of lateral movement. The shear wall at odd and even floors also reduces displacement effectively but not as much as the full combination. Overall, integrating both shear walls and bracing offers the most efficient structural performance in minimizing lateral displacements.

V. CONCLUSION

- Structural damages caused by blast loading are the combination of both immediate effects and consecutive hazards, among which is progressive collapse. This catastrophic failure mode occurs when the initial failure of one or several key load-carrying members causes a more widespread failure of the circumventing members what leads to consummate collapse of the whole structure.
- Consequently, it is of great paramount to investigate and ameliorate the replication of structures to blast loading. A bomb explosion nearby a building can cause catastrophic damage to the building's external and internal structural frames, collapsing of walls and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can cumulate to inhibit or avert timely avoidance, thereby contributing to supplemental casualties.
- The main intent of this Study is to through light on the design of blast resistant buildings and to know the response of a structure when subjected to blast loads utilizing ETABS software with prominence given on different Standoff distances of the blast and incorporating different charge weights of TNT according to the IS CODE 4991.
- This study examined at blast loads applied to buildings with shear walls and bracing.
- According to the findings of the study, shear walls produce better economic results than bracing.
- For bracing, we replaced bracing with BRB and analyzed blast loads again because BRB delivers economic results when compared to bracing. As a consequence of the study, we must recommend that if you only use bracing, use BRB instead of conventional bracing to minimize blast effects on the building.
- In a subsequent study, we looked at two more cases: buildings with bracing and shear walls and buildings with shear walls on odd and even floors. The analysis concluded that buildings with shear walls and bracing are the most economical than any other building, and when compared to buildings with shear walls on odd and even floors, buildings with shear walls on odd and even floors are the most economical.





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