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ANALYTICAL ASSESSMENT OF DIFFERENT STRUCTURAL FRAMES SUBJECTED TO EXTREME LOADS

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ABSTRACT
In the present scenario, structural engineers should design a structure considering blast loads. To guide them, this paper compares the response of different structural frames subjected to blast loads. The frames analyzed in this paper are rigid frames, braced frames, symmetrical outrigger frames and unsymmetrical outrigger frames. The frames are subjected to extreme loads with variation in the distance of the application of loads. The main objective of this work is obtaining the frame with minimum displacement which can be used in construction in areas subjected to bomb blasting frequently.

Index Terms—blast, braced, extreme loads, outrigger, rigid, symmetrical, unsymmetrical

1 INTRODUCTION

Now a days, a number of tragic terrorist attacks, around the world have resulted in the initiatives to study the resistance of structures to blast. To reduce hazard of such attacks there have been many research projects undertaken to develop blast resistant mechanisms. The main aim of these efforts is to protect the safety of the occupants of the building, the rescue workers and those who are around the building whom can be killed or injured by the collapse of the structure and the falling debris. Progressive collapse prevention is one of the main areas of research and developments. A building with minimal damage can be constructed from a structural engineering point of view. This has been done for years and continues to be done for militarily sensitive and other critical buildings that are necessary to be functional and occupied even after a bomb attack on them. Of course, designing such a highly protected building requires a significant amount of funding as well as resources. In some cases, the aesthetics and internal functionality of a structure are sacrificed to achieve the objective. Although in case of military installations, the high cost and bunker like appearance of a building can be justified, however, for civilian buildings, such high costs cannot be afforded and the loss of aesthetics may not always be acceptable. This was because of the assumption that civilian buildings had a very low probability to be a target of terrorist attack.

To provide the blast resistance a structural engineer should understand and interpret blast phenomenon deeply. He should also analyze the main and secondary effects on the structure.

2 EXPLOSION

An explosion is a very rapid release of stored energy characterized by audible blast. The energy released is divided into two different phenomena which are thermal radiation and coupling with air and ground, known as air blast and ground shock. Air blast is the principle cause of the damage to a building exposed to blast loading. On the other hand, the ground shock -wave propagates by compressing the air molecules in its path, thus producing the ambient overpressure or the incident pressure. The effect of bomb explosion depends on many factors like the type and size of bomb, distance from the structure, whether internal or external blasting, type of the structure. In this study the blast loads are applied along with the dead and live loads on the structure. The blast loads applied are ranging from 5kg to 1000kg with a varying distance of 5m,10,50m and 100m.

2.1 BLAST WAVES SCALING LAWS

All the parameters of a blast are dependent on the amount of energy released during the detonation as a blast wave and the distance of the explosion. The scaling distance is measured from the equation

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

where Z-scaled distance
R-distance from the structure
W-weight of the explosive in kg

The peak over pressure is calculated from the graph depending on the scaled distance.

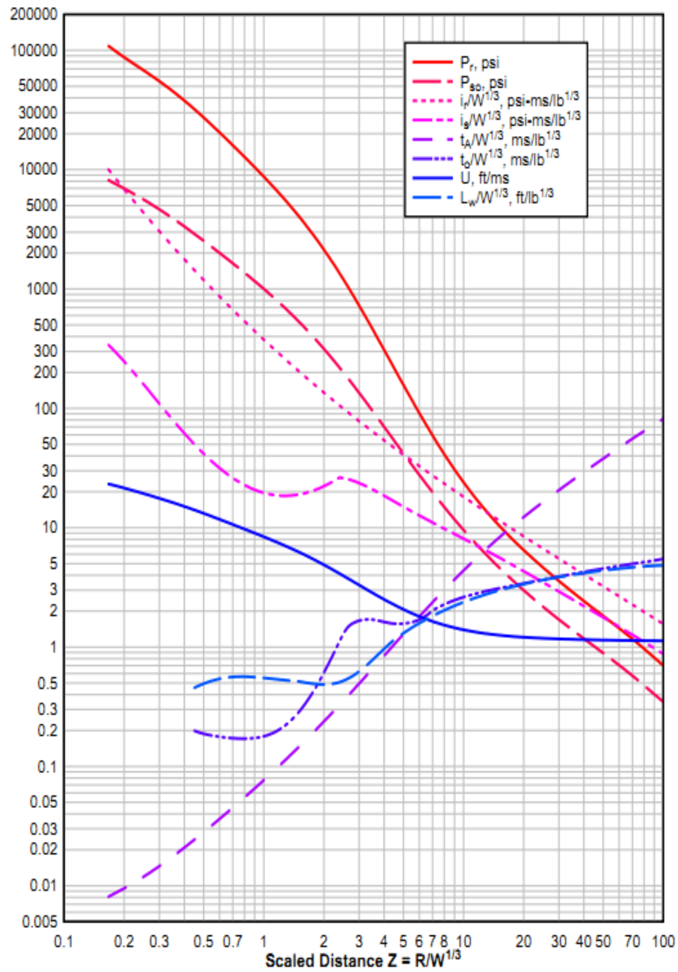

Fig.2.1 Peak over pressure

3 MODELLING

The plan of the structure is drawn using AutoCAD and it is shown in the Fig.3.1.

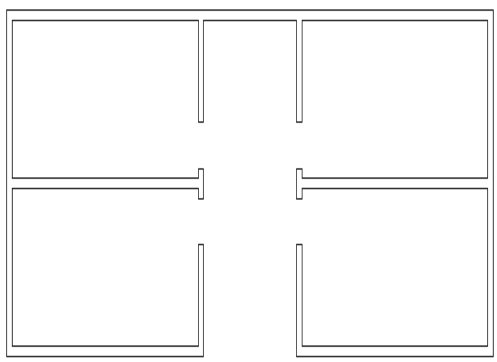

Fig.3.1 Plan of the structure

The size of the beams are 300x300 mm and columns are 400x400 mm. The structure is of 20 storeys with each storey height of 4m and the base height is 4.5m. Number of bays in X-direction are 5 bays and in Y-direction 4 bays.

Location of the beams and columns are shown in the Fig.3.2.

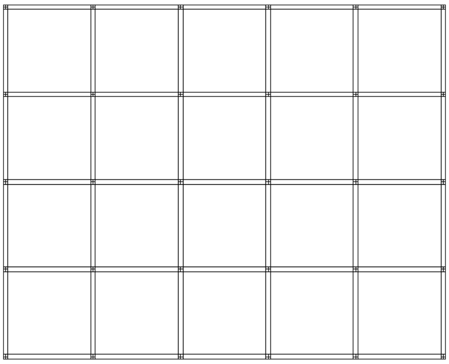

Fig.3.2 Location of beams and columns

The frames are modelled in ETABS with the above dimensions and the calculated loads are applied on the frames and analyzed.

3.1 RIGID FRAMES

A rigid frame is the structure connected to resist the moments induced at the joints. The supports are fixed and resist the moments due to the loads acting on the frame. Modelling of rigid frames is shown in the fig.3.3.

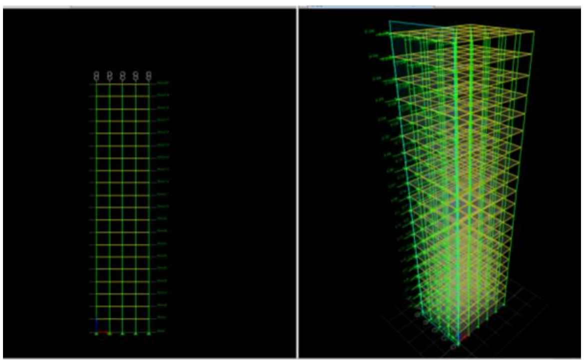

Fig.3.3 Modelling of rigid frames

3.2 BRACED FRAMES

Braced frames are the modification of the rigid frames. Braces are provided to resist the lateral loads acting on the frames. The braces are provided with steel sections to the resist the loads. The braces act as a column for transmitting the axial loads. Modelling of braced frames shown in Fig.3.3.

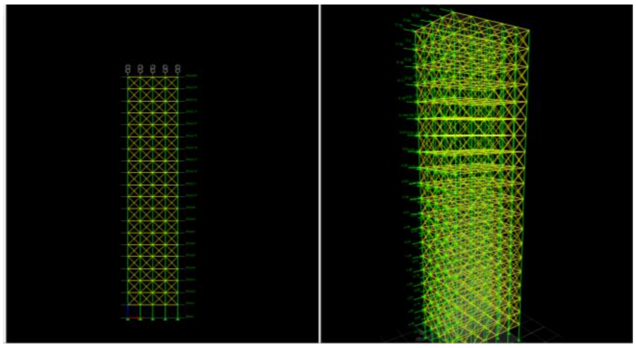

Fig.3.3 Modelling of braced frame

3.3 SYMMETRICAL OUTRIGGER FRAME

As the rigid frames or braced frames can provide adequate stiffness only for a certain height outrigger frames are provided. Outrigger frames are provided with a shear core. To increase the lateral stiffness the exterior frames are tied to the shear core together with outrigger trusses. The columns connected to the outriggers resist the lateral force and rotation of the core.

Outriggers are of two types. They are symmetrical outrigger frames and unsymmetrical outrigger frames.

Modelling of symmetrical outrigger frame is shown in Fig.3.4.

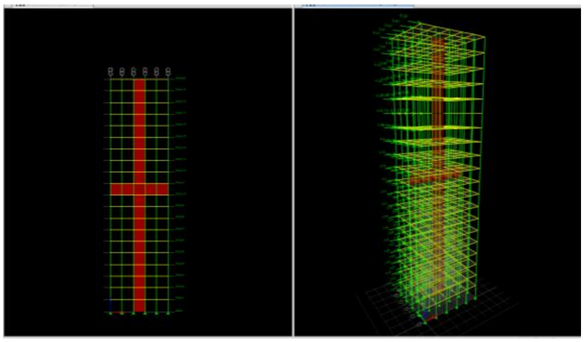

Fig.3.4 Modelling of symmetrical frame

3.4 UNSYMMETRICAL OUTRIGGER FRAME

In unsymmetrical outrigger frames the outrigger trusses are provided only on the side where most of the lateral loads act.

Modelling of unsymmetrical outrigger frame is shown in Fig.3.5.

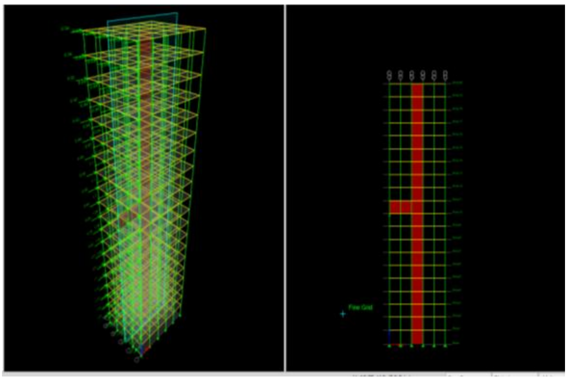

Fig.3.5 Modelling of unsymmetrical frame

4 RESULTS

When a load of 5kg is acted at a distance of 5m, the displacements are shown in the Table.4.1 and Fig.4.1 shows the graphical representation of the displacements.

Table.4.1 Displacements due to 5kg loading

Storey	Load(kN)	Displacement(mm)			
		Rigid	Braced	Symmetrical outrigger	Unsymmetrical outrigger
Storey 20	0.083	3.2	0.7	1.2	5.6
Storey 19	0.083	3.2	0.7	1.2	5.6
Storey 17	0.0896	3.2	0.7	1.1	5.5
Storey 15	0.09	3	0.7	1.1	5.4
Storey 13	0.12	2.9	0.7	1	5.1
Storey 11	0.17	2.8	0.7	0.9	4.1
Storey 9	0.22	2.6	0.7	0.9	1.6
Storey 7	0.28	2.3	0.6	0.7	0.4
Storey 5	0.41	2	0.6	0.5	0.1
Storey 3	0.83	1.5	0.6	0.3	0.1
Storey 1	3.86	0.7	0.6	0.1	0.04

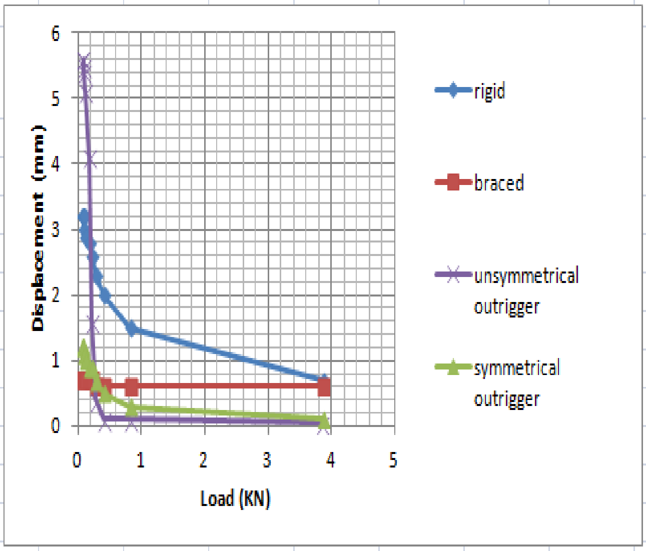

Fig.4.1 Results under 5kg loading

When a load of 100kg is acted at a distance of 10m, the displacements are shown in the Table.4.2 and Fig.4.2 shows the graphical representation of the displacement.

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Table.4.2 Displacements due to 100kg loading

Storey	Load(kN)	Displacements(mm)			
		Rigid	Braced	Symmetrical outrigger	Unsymmetrical outrigger
Storey 20	0.28	11.2	3	3.9	4.8
Storey 19	0.29	11.2	3	3.9	4.9
Storey17	0.33	11	2.9	3.7	5
Storey 15	0.36	10.7	2.9	3.5	5
Storey 13	0.62	10.4	2.8	3.3	4.7
Storey 11	0.69	9.9	2.7	3.1	3.7
Storey 9	0.83	9.3	2.7	2.9	1.3
Storey 7	1.65	8.6	2.6	2.5	0.1
Storey 5	2.76	7.5	2.6	1.8	0.2
Storey 3	6.48	5.9	2.5	1	0.2
Storey 1	65.49	3	2.5	0.2	0.04

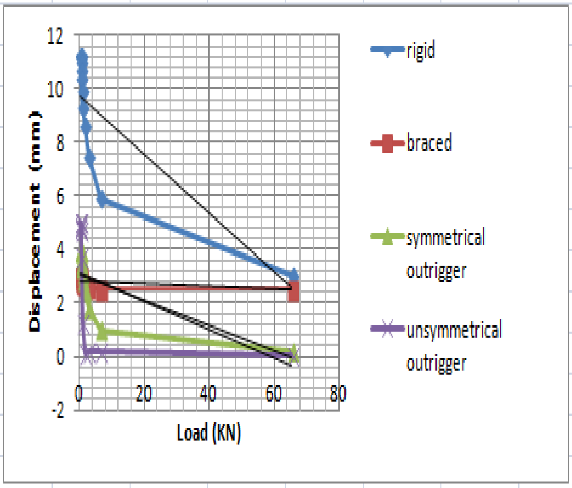

Fig.4.2 Results under 100kg loading

When the load of 500kg is applied at a distance of 50m, the displacements are shown in the Table.4.3 and Fig.4.3 shows the graphical representation of the displacements in each storey.

Table.4.3 Displacements due to 500kg loading

Storey	Load(kN)	Displacement(mm)			
		Rigid	Braced	Symmetrical outrigger	Unsymmetrical outrigger
Storey 20	0.37	7.6	1.2	3.1	3.4
Storey 19	0.41	7.5	1.2	3.1	3.5
Storey 17	0.47	7.3	1.1	2.9	3.7
Storey 15	0.5	7	1.1	2.6	3.6
Storey 13	0.55	6.6	1.1	2.3	3.6
Storey 11	0.62	6	1	2.1	2.7
Storey 9	0.8	5.4	0.9	1.8	0.4
Storey 7	0.83	4.5	0.9	1.4	0.5
Storey 5	0.91	3.5	0.9	0.8	0.7
Storey 3	0.94	3	0.8	0.5	0.4
Storey 1	0.97	1	0.8	0.1	0.1

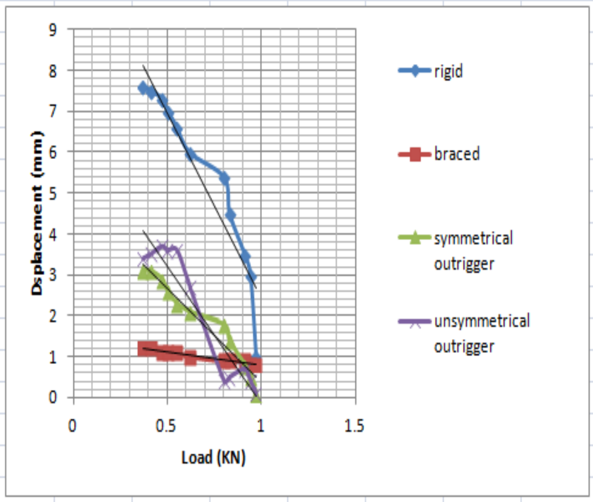

Fig.4.3 Results under 500kg loading

When a load of 1000kg is acted at a distance of 100m, the displacements are shown in Table.4.4 and Fig.4.4 shows the graphical representation of the displacement in each storey.

Table.4.4 Displacements due to 1000kg loading

Storey	Load(kN)	Displacement(mm)			
		Rigid	Braced	Symmetrical outrigger	Unsymmetrical outrigger
Storey 20	0.41	6.3	1	2.6	4.2
Storey 19	0.41	6.2	0.9	2.5	4.3
Storey 17	0.41	6	0.9	2.4	4.5
Storey 15	0.41	5.7	0.9	2.2	4.5
Storey 13	0.48	5.3	0.8	2	4.3
Storey 11	0.48	4.8	0.8	1.8	3.3
Storey 9	0.55	4.2	0.7	1.6	0.9
Storey 7	0.55	3.6	0.7	1.3	0.2
Storey 5	0.69	2.8	0.7	0.9	0.4
Storey 3	0.69	1.8	0.6	0.4	0.3
Storey 1	0.69	0.8	0.6	0.1	0.1

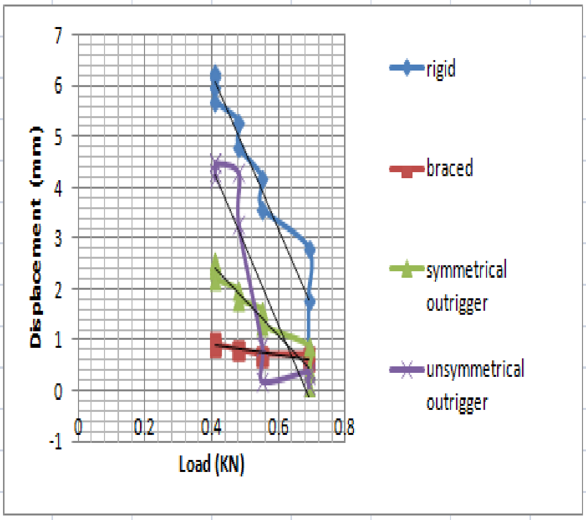

Fig.4.4 Results under 1000kg loading

5 CONCLUSION

- The displacements of all the loads are compared and it shows that **"Braced Frames"** are the most resistant frames for the extreme loads acting on the structure.
- **"Symmetrical Outrigger Frames"** can also be used when braced frames cannot be constructed in the areas where explosion is more frequent.

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