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NONLINEAR DYNEMIC ANALYSIS OF G+7 BUILDING UNDER BLAST LOAD BY USING SAP 2000

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ABSTRACT:

Nonlinear dynamic analysis is a crucial tool for assessing how structures respond to blast loading. In this study, a G+7 building was analyzed using the SAP2000 software. The objective was to understand the behavior of the building and assess its integrity and safety under blast loading. The nonlinear dynamic analysis took into account the interactions between various structural components, such as beams, columns, and slabs, as well as nonlinear material behavior, time-dependent effects, and influences on the environment. The blast loading was applied in the form of a pressure-time curve, mimicking the effect of an explosion. To determine the dynamic reaction of the building owing to blast load, a parametric research is conducted on a multistory G+7 building. Software called SAP2000 has a model of the structure. The outcomes are shown as Time Histories for various Charge weights of 10 kg, 20 kg, and 30 kg as well as various Standoff distances of 10 m, 20 m, 30 m, 40 m, and 50 m. The analysis' findings offer insightful information about the structure's dynamic behavior and performance under blast loading. This information can be used to optimize the design and retrofit strategies for enhancing the blast resistance of similar structures and improving the safety of occupants during such extreme events.

Keywords: Blast load, G+7 building, retrofitting measures, Time History analysis and SAP2000

I. INTRODUCTION

Nowadays terrorism is one of the major problems in many countries. It is very difficult to identify such problems. Disasters caused by humans differ from Natural catastrophes including earthquakes, floods, and hurricanes, among others. Explosive materials are used in several major terrorist activities. The inside and exterior of the structure can be destroyed and damaged by these explosive materials. The design of the building, the materials utilized, and the charge weight all affect how severe the damage is. Building damage can be minimized if the structures are correctly constructed for these abnormal stresses. Retrofitting of buildings is also required to guarantee the security of existing structures against such catastrophes. Building structural damage is a major contributor to the deaths from explosions. Following are little damage to buildings due to blast loading worldwide.

In 1968, a gas leak resulted in an explosion in a Ronan Point apartment on the 18th floor of a London building. The loss of an exterior wall led the higher floors to fall, and as a result of the effect of the collapsing upper levels, the lower floors also collapsed. In 1995, a truck bomb containing high explosives was detonated 3–5 meters away from the north face of the Murrah Federal Building in Oklahoma City (Figure 1a). The Khobar Towers building's facade wall was demolished in 1996 by an explosion that left a crater 17 meters in diameter and 5 meters deep in Dhahran, Saudi Arabia. The explosion also severely damaged surrounding buildings, breaking a lot of glass within the structure. It was immediately in the path of the World Trade Center twin towers' collapsing debris on September 11, 2001. The north face of the structure was severely gashed, and major structural framing was lost. However, the building managed to hold its own and the collapse did not spread.

After the 1968 collapse of the Ronan Point flat in England, structural engineering research departments were compelled to focus their research on structures that gradually collapse as a result of blast loads. Although there are global norms, regulations, and criteria, it is important to comprehend how a building gradually collapses under blast loads. This project's primary goal is to investigate how buildings behave structurally when subjected to blast loads. Knowing the type of building collapse and the potential for repairs in the event of a partial collapse is helpful.

II. LITERATURE REVIEW

Kauthammer et al., (2002) For blast loadings, a progressive collapse analysis and damage assessment approach was created. It was done to dynamically analyze planar frames under progressive collapse, which takes into account both geometry and material nonlinearities. The geometric stiffness matrix takes into account geometric nonlinearity (P-). In order to account for material nonlinearity, beam-column elements are fitted with a lumped plasticity model.[1]

Williamson et al., (2002) To forecast member failure, the algorithm uses a damage index with a value between 0 and 1. The loss of stiffness and strength during cyclic loading is taken into consideration using a damage model. [2]

Alexander, (2003) The techniques for predicting the consequences of bomb blasts on buildings were investigated. Using streamlined analytical methods, modest estimates of the blast's impacts on buildings were obtained. For the precise prediction of blast loads on commercial and public buildings, numerical approaches such as Lagrangian, Eulerian, Euler-FCT, ALE, and finite element modeling are used. [3]

Nelson Lam et al. (2004) Buildings with fragile storeys that collapse. In order to successfully prioritize retrofitting work on the existing buildings, a credible seismic risk model for this class of buildings must be developed. [4]

Pandey et al., (2006) The consequences of an external explosion were studied on the reinforced concrete exterior shell of a conventional nuclear containment plant. The analysis was carried out all the way through using the appropriate non-linear material models. The above-mentioned model has been used to provide an analytical framework for the finite element algorithm DYNAIB. [5]

Shankar, (2006) Redundancy, local resistance, or interconnectedness were explored for the Ronan Point, the Murrah Building, WTC 1 and 2, and WTC 7. It was determined that redundancy is just one method for lowering a building's vulnerability to disproportionate collapse. [6]

Zhongxian and Yanchao, (2008) The Direct Simulation Method and Alternative Load Path Method were presented as an overview of the current progressive collapse analysis techniques. The direct approach produces accurate forecasts of structural collapse under blast loads but is time-consuming and necessitates a thorough understanding of structural dynamics, damage mechanics, dynamic material properties, and computational skills. A different method has a low accuracy cost but is quite simple to utilize. To get around the drawbacks of the strategies mentioned above, a new approach was suggested. The alternative load path method, which ignores non-zero structural conditions and damage in the structural components when progressive collapse starts, does not provide as accurate predictions of structural progressive collapse as the suggested method does. [7]

Aleem Ullah et al. (2016) Analyze the characteristics of the incident blast wave for both ground and air blasts. Analyses and empirical findings are compared quantitatively, utilizing the Unified Facilities Criteria (UFC3-340-02) as a guide. Over the past few years, concern over how exposed structures are to blast loads has increased. Terrorist attacks, unintentional explosions, and natural disasters are just a handful of the numerous factors that might lead to blast events. To ensure the safety and security of structures, it is essential to assess how they respond to such high loading conditions. [8]

III. METHODOLOGY

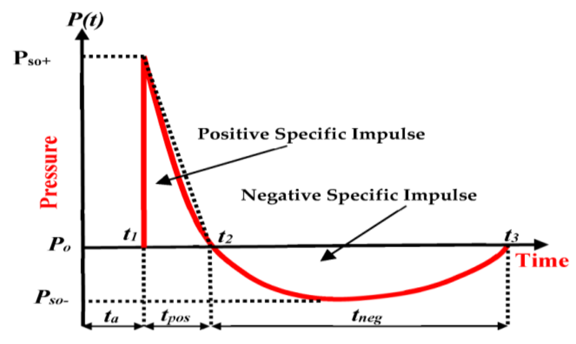
Here is a step-by-step methodology for performing nonlinear dynamic analysis of a G+7 building under blast load using SAP2000 software: It is important to note that dynamic analysis under blast loads can be a complex and specialized field. Consulting with a structural engineer experienced in blast analysis and protection is recommended for a comprehensive and accurate analysis.

1. Create the 3D model of the G+7 building in SAP2000 software using the appropriate geometry and structural elements. Include all relevant components such as columns, beams, slabs, walls, and foundations.
2. Define the material2. Define the material properties: Assign appropriate material properties to each structural element based on the building's design. This includes specifying the mechanical properties such as modulus of elasticity, Poisson's ratio, yield strength, and density.
3. Define the load: Define the blast load applied to the structure. This may include specifying the blast intensity, duration, and location. You can apply the blast load as an equivalent dynamic load using SAP2000's load types.
4. Define the analysis parameters: Set up the analysis parameters such as analysis type, time step size, and analysis duration. For nonlinear dynamic analysis, it is common to use the time History analysis method with appropriate control parameters.
5. Define the boundary conditions: Specify the boundary conditions for the model, including fixing appropriate nodes or applying constraints. This ensures that the model is properly constrained to represent the interaction with the ground and neighboring structures.
6. Perform the analysis: Run the dynamic analysis using SAP2000's analysis capabilities. This will solve the equations of motion considering the nonlinear structural response due to the blast load.
7. Evaluate the results: After the analysis is complete, examine the output results including deflections, stresses, and accelerations. Check whether any critical elements have exceeded allowable limits in terms of displacement or stress.
8. Perform retrofit designs if necessary: If the structure is found to be inadequate or damaged, consider implementing retrofit measures or modifications to improve the structure's blast resistance. Re-analyze the structure after implementing retrofit designs to evaluate the effectiveness.
9. Document the analysis: Prepare a detailed report documenting the modeling assumptions, analysis procedure, and results. Include recommendations for any required modifications or retrofit measures.

3.1. NONLINEAR DYNEMIC ANALYSIS

A nonlinear dynamic study for different charge weights using G+7 The various standoff lengths for weights of 10 kg, 20 kg, and 30 kg, respectively, are 10 m, 20 m, 30 m, 40 m, and 50 m. Maximum displacements are a means to describe how standoff distance and charge weight affect the height of construction cases. Later, the same analysis is carried out for a G +7 storey building with a charge weight of 20 kg set at a distance of 20 m using reinforcing techniques such column jacketing and bracing.

Calculating blast loads requires knowledge of the time vs. pressure variation curve since it can be used to foretell how an explosion will impact a structure. The pressure of the blast wave is depicted by this curve as it varies over time. It gives vital details regarding the length and force of the blast wave, which have a direct bearing on the structural reaction and potential harm to a structure or infrastructure. In most cases, experimental data or mathematical modeling are used to derive the time vs. pressure variation curve. It explains the dynamic nature of the blast wave as it moves through the atmosphere and interacts with the structure.



Where;

P (t) represents the event overpressure at any instant;
P0 is atmospheric pressure;
t_{pos} and t_{neg} are the positive and negative phase lengths for the incident blast wave, respectively;
Pso^{+} and Pso^{-} are the peak positive incident overpressure and peak negative incident under pressure, respectively;

The arrival time is t_a;

Fig 1. Idealized pressure-time variation curve

3.2. SCOPE OF STUDY

Nonlinear dynamic analysis is a technique for examining how buildings respond to applied loads, such blast loads. Dynamic blast loads can significantly affect a building's nonlinear behavior. The scope of nonlinear dynamic analysis of buildings under blast loads is comprehensive and involves considering the complex behavior of materials and structures, accurately modeling blast loads, evaluating structural response, and optimizing the design for enhanced blast resistance.

3.3. OBJECTIVES OF STUDY

A thorough literature study is carried outside to describe the goals of the thesis. The literature survey is reviewed and quickly outlined as follows:

1. Evaluation of the building's structural response to an explosion is the main goal of the dynamic study of a G+7 storey building under blast load.
2. The finite element approach is used to represent a building with barriers on one side. Indian Standard Codes were used to design the structure.
3. According to Unified Facilities Criteria (UFC 3-340-02), the blast loads are computed. By adjusting stand-off distances and charge weights, the blast load is distributed along the height of the building. The three-dimensional building is subject to the same scrutiny.
4. In the end, the structure's displacements are determined, and retrofitting procedures are carried out to reduce the dynamic impact of a building caused by blast load.

IV. BUILDING MODELLING AND ANALYSIS

4.1. PROPERTIES OF BUILDING

Table 1: Geometrical properties & location factors

Properties	G+7 building
Grade of concrete	M20
Grade of steel	Fe415
Poisons ratio	0.2
Cross section of beam	0.25m × 0.4m
Cross section of column	0.4m × 0.4m
Thickness of slab	0.15m
Height of each floor	3m
Height of structure	24m

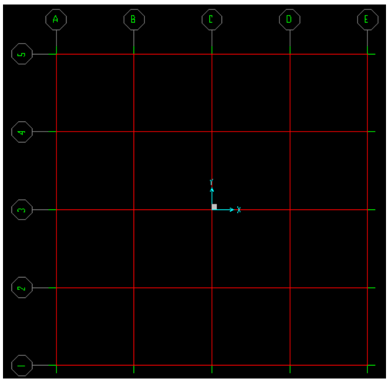


Fig 2. Plan layout of structure

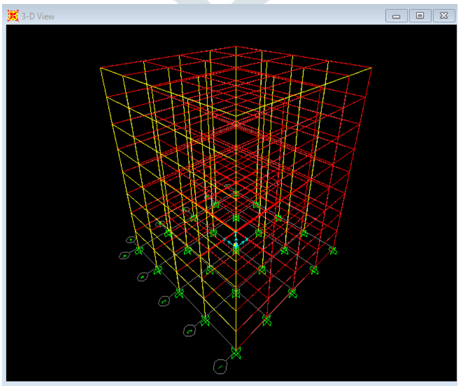


Fig 3. 3D model

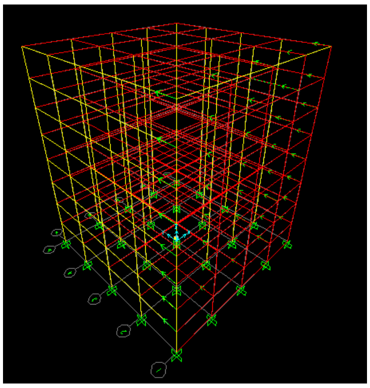
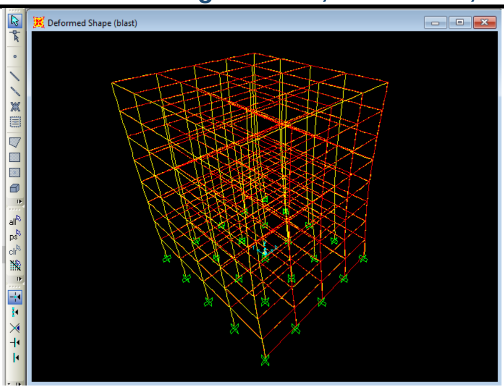


Fig 4. Loading on structure



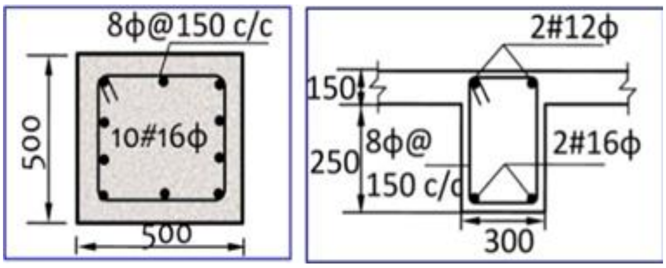


Fig 5. Deformation

Fig6. Reinforcement details of Beam,column

V. RESULTS AND DISSCUSIONS

5.1. ESTIMATION OF BLAST LOAD

The process for calculating blast load using empirical formulae provided by academics. The following crucial factors go into calculating the blast load:

Step 1: Calculate the RG (the distance between the point of interest and the explosion):

$$R_G=\sqrt{R^2+H^2} \quad \text{-(i)}$$

Where;

RG is the distance between the blast and the target. written in the m.

R Distance between the point of interest and the detonation source. standoff range in meters.

H is Height of building in m.

Step 2: Calculate (Z) Scaled distance:

$$Z=\frac{R_G}{W^{1/3}} \quad \text{- (ii)}$$

Where;

Z is the scaled distance or proximity factor. $m/kg^{1/3}$

R_G is the distance between the blast and the target. written in the m, **W** stands for the charge weight.kg

Step3: Calculate peak over pressure (P_s)

$$P_s=678.4\times\frac{W}{R_G^3}+294\sqrt{\frac{W}{R_G^3}} \quad \text{- (iii)}$$

Where;

P_s is Peak over pressure expressed in kPa.

Step 4: Calculate coefficient of reflected over pressure (C_r):

$$C_r = 3P_s^{1/4} \quad \text{- (iv)}$$

Where;

C_r is coefficient of reflected pressure.

Step 5: Calculate reflected over pressure:

$$P_r= C_r\times P_s \quad \text{- (v)}$$

Where;

P_r is reflected over pressure (kPa)

Step 6: Calculate arrival time (t_a) :

$$t_a = \frac{8534\times(\frac{R_G}{W^{1/3}})^{-0.996}}{a_0} \quad \text{- (vi)}$$

Where;

In air, sound travels at a speed of 340 m/s, or a0.

Step 7: Calculate positive phase duration (t_d):

$$t_d = 10W^{1/3} \quad \text{- (vii)}$$

Where;

W is charge weight kN.

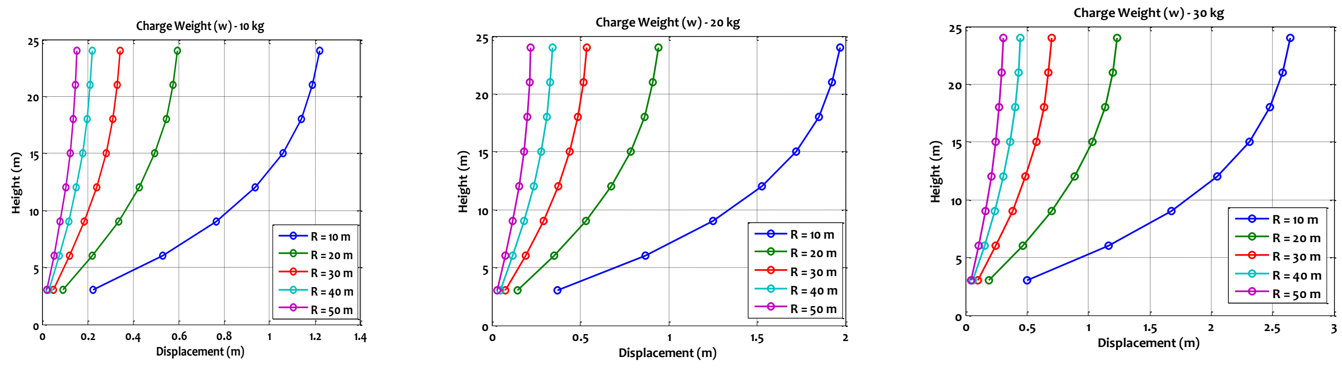
Step 8: Calculate Blast load:

Blast load (P) = P_r (surface area of wall)

$$P= P_r\times(B\times H) \quad \text{-(viii)}$$

Where; **P_r** is reflected pressure, **B** is width of building**,** **H** is total height of building.

5.1. Nonlinear dynamic analysis for different charge weights with different standoff distance



(a) (b) (c)

Fig. 7 (a) (b) (c) shows the maximum displacements at each floor level for the G+7 building for various charge weights and standoff lengths.

For a charge weight of 10 kg, the maximum displacement at the top floor is reduced to 51%, 72%, 82%, and 87% as the standoff distance is increased. For a charge weight of 20 kg, the maximum displacement at the top floor is reduced to 52%, 72%, 83%, and 88%. The maximum displacement at the top floor is decreased for a 30 kg charge to 53%, 73%, 83%, and 88%.

5.2. RETROFITTING MEASURES:

The aftermath of a terrorist attack or blast explosion that causes considerable, varying-degree damage to a number of structures, including full, partial, and minor damage. We offered a technique in which the bulk of these blast-damaged buildings may be transformed into blast-resistant structures by using a few Retrofitting measures, allowing for their safe re-use. 1. Local Jacketing, 2.Bracings (single, double diagonal bracings)

5.2.1. Local Jacketing:

Local jacketing involves reinforcing specific structural elements of a building to improve their resistance to blast loads. This method is particularly effective when the building is modeled in advanced software such as SAP2000. In the case of a G+7 building, the nonlinear dynamic analysis method is employed to evaluate the response of the structure under blast loads. This analysis method takes into consideration the nonlinear behavior of materials and the dynamic characteristics of the blast load, providing more accurate results compared to linear analysis methods.

5.2.1.1. Nonlinear Response of (G+7) Structure at 20 kg Charge Weight and 20 m Standoff.

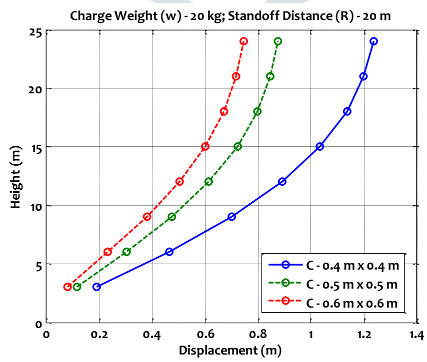


Fig 8: Nonlinear Response of (G+7) Structure at 20 kg Charge Weight and 20 m Standoff.

A G+7 structure with a 20 kg charge and a 20 m standoff distance was visible. When the column size is increased 0.4 m × 0.4 m to 0.5 m × 0.5 m and 0.6 m × 0.6 m, respectively, the maximum displacement at the top floor is reduced by 29% and 40%.

5.2.2. Bracings

Retrofitting techniques refer to the methods used to strengthen or enhance the structural integrity of existing buildings to withstand specific loads or seismic events. The goal of retrofitting is to increase the building's resistance to blast-induced forces and stop progressive collapse. There are two types of bracing systems used in the nonlinear dynamic analysis of a G+7 building under blast load. SAP2000 is a popular software tool widely used for structural analysis and design. It provides advanced capabilities for modeling, analyzing, and visualizing structural behavior.

5.2.2.1. Single diagonal bracings:

In retrofitting the single diagonal bracings of the G+7 building for blast load, this involves inputting the geometry and properties of the building components, such as columns, beams, and slabs, along with material properties, support conditions, and connection details. It is crucial to specify the blast load characteristics, such as the blast strength, duration, and direction, once the building model has been developed. These variables are essential for modeling the dynamic reaction of the blast-damaged building. Utilizing SAP2000, the nonlinear dynamic analysis is then performed.

5.2.2.2. G+7 structure's nonlinear response before and after receiving single diagonal bracings

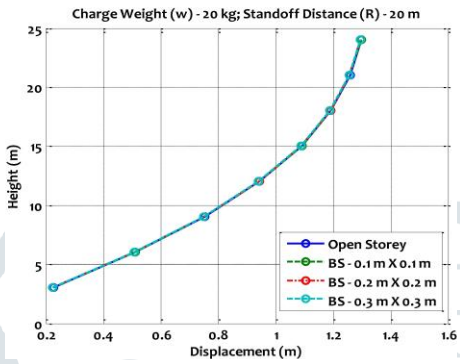


Fig 8: G+7 structure's nonlinear response before and after receiving single diagonal bracings

We discovered that single diagonal bracings of sizes 0.1 m 0.1 m, 0.2 m 0.2 m, and 0.3 m 0.3 m reduced the maximum displacement at the top floor by 0.04%, 0.12%, and 0.26%, respectively, in the blast-affected phase at the ground level. Single diagonal bracings have minimized displacement that is much less than local jacketing.

5.2.3. DOUBLE DIGONAL BRACINGS

Double diagonal bracings are commonly used in retrofitting measures for improving the blast resistance of buildings. In the case of a G+7 building, which is a 7-story building with a ground floor, double diagonal bracings can be strategically placed in key locations to enhance the building's overall stability and resistance to blast loads. Double diagonal bracings consist of two diagonal members that intersect at a central node, forming an X-shaped configuration. This configuration offers increased structural integrity and prevents the building from collapsing or suffering severe damage during a blast event.

5.2.3.1. G+7 structure's nonlinear reaction before and after receiving double diagonal bracings

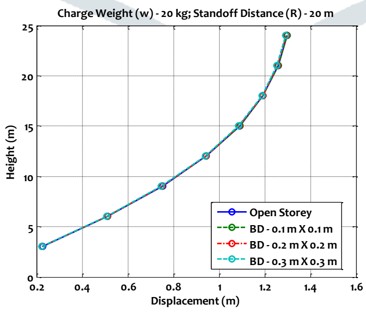


Fig 9: G+7 structure's nonlinear reaction before and after receiving double diagonal bracings

In the blast-affected phase at the ground floor, we found that double diagonal bracings of sizes 0.1 m 0.1 m, 0.2 m 0.2 m, and 0.3 m 0.3 m reduced the maximum displacement at the top floor by 0.03%, 0.11%, and 0.4%, respectively. The lowered displacement in double diagonal bracings is significantly less than that of local jacketing and single diagonal bracings.

VI. CONCLUSIONS

1. The neighboring explosion could cause harm to the building. Potential causes of injury and possibly death include exposure to an explosion wave front, a building collapsing, things striking one another, fire, and smoke.

2. The blast load for a surface explosion was computed and simulated on a model building using SAP2000, the industry-standard tool for the Dynamic Analysis of structures.
3. A record of blast load through time (blast load-time history), as stated in the literature that was available, was what was meant by loading.
4. The maximum displacements at specific joints for the G+7 building with different charge weights of 10 kg, 20 kg, and 30 kg at different standoff distances of 10 m, 20 m, 30 m, 40 m, and 50 m are calculated using SAP2000's non-linear dynamic analysis.
5. We discovered that maximum displacement gradually decreases as standoff distance rises. By offering retrofitting techniques, the maximum displacement is reduced.
6. For G + 7 structures with charge weights of 20 kg and standoff distances of 20 m, there are two types of bracings: 1. local jacketing and 2. Bracings (single diagonal and double diagonal bracings).
7. Compared to bracing, local jacketing significantly reduces displacement.
8. Local jacketing thereby provides defense against surface blasts or explosions.

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