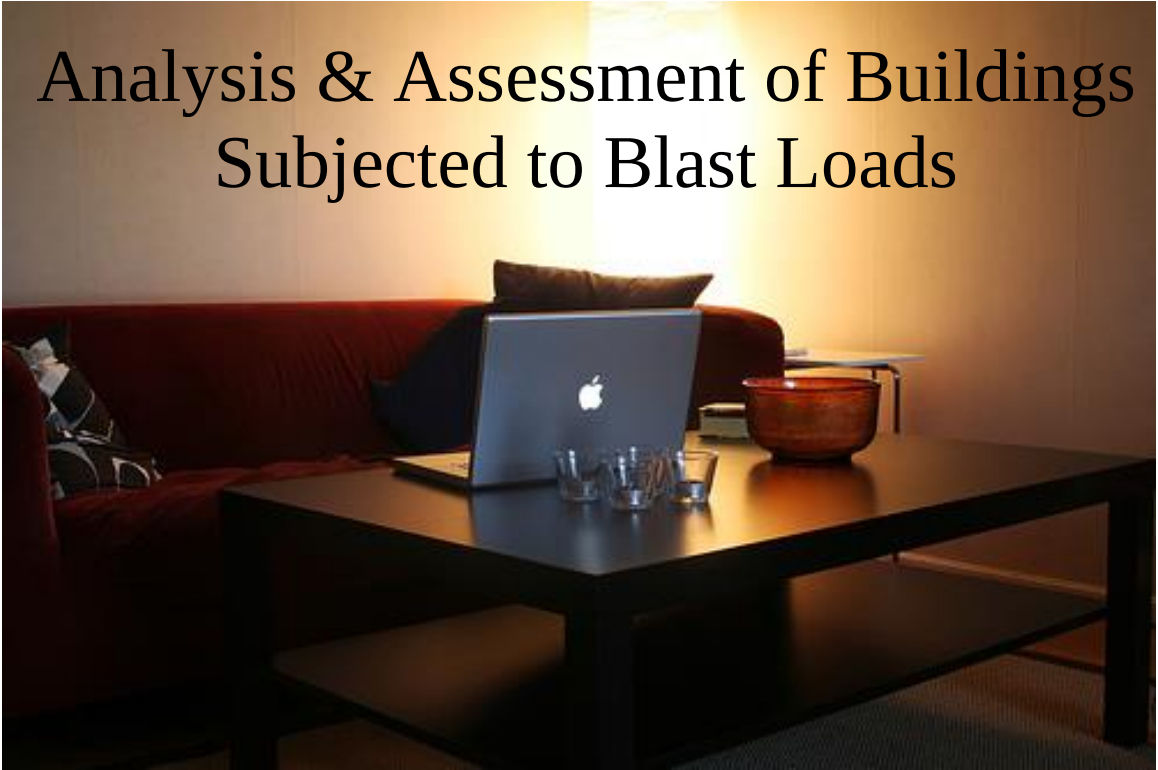




Analysis & Assessment of Buildings Subjected to Blast Loads

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By

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3 PDH HOURS

“Analysis & Assessment of Buildings Subjected to Blast Loads”

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COURSE CONTENT

Introduction

This course is about Analysis & Assessment of Buildings Subjected to Blast Loads

This course is very useful for researchers, under graduate, post-graduate students, professional engineers, academics, PhD holder in structural engineering field. This course learns the engineers how to easily do the structural assessment of buildings subjected to blast loads.

Learning Objectives

At the conclusion of this course, the student will be able to evaluate the structural assessment of buildings subjected to blast loads and will

- Be able to provide engineers with the required technical data which enable them to take the right decision, if that structure must be retrofitting or not.
- Be able to do the protective design for blast-resistant structures
- Be able to do the required progressive collapse analysis to show if this building will collapse or not due to blast loading effects.

Protective Design Strategy Of Blast-Resistant Structures by the followings:-

Reduce Blast Demands, HOW?

The Main Strategy for Blast-Resistance Structures Design is to Reduce Blast Demands.

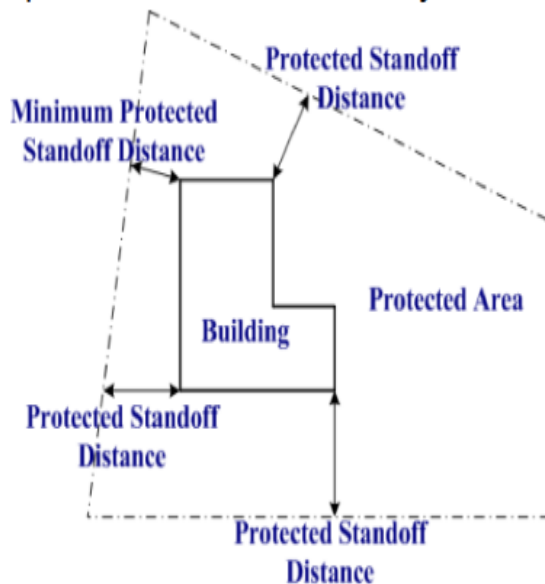
Blast demands mean to reduce deformation in structural and non-structural building components. This is achieved through:

**Increase Standoff Distance

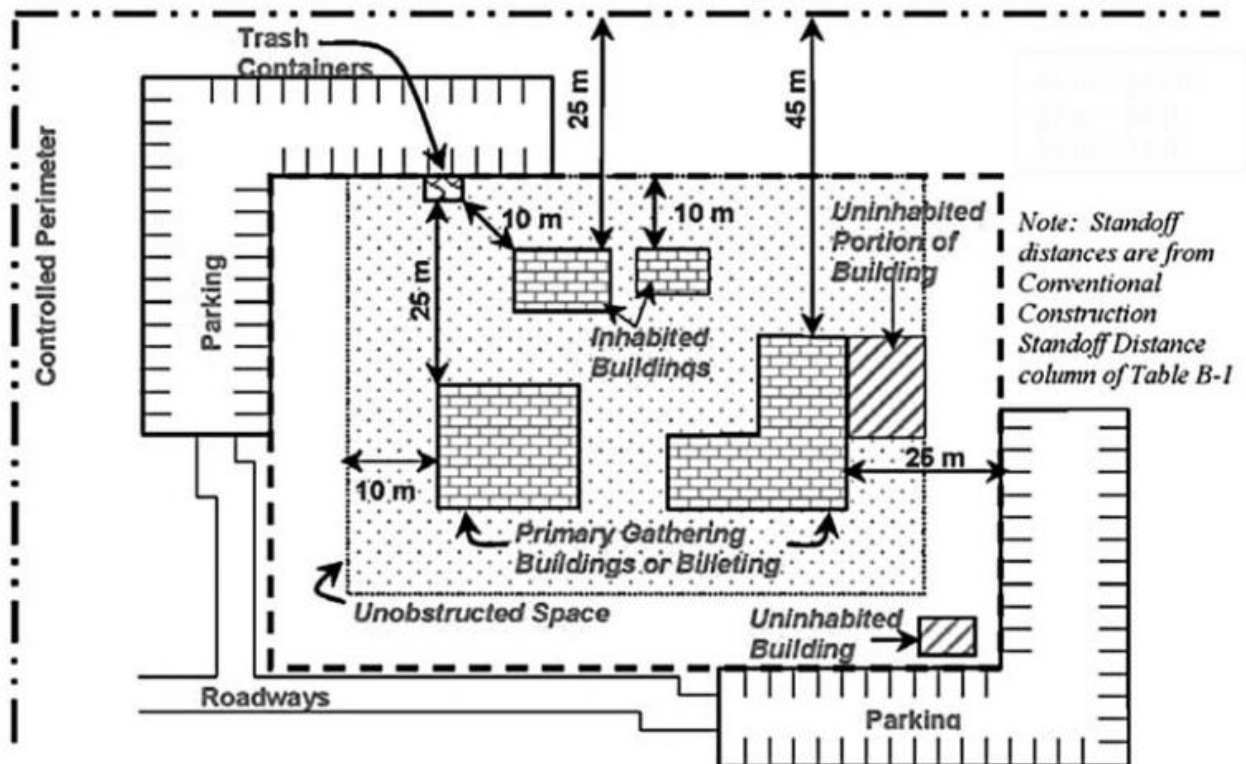
Providing sufficient protection by increasing protected standoff distances against external attacks.

Standoff Distance

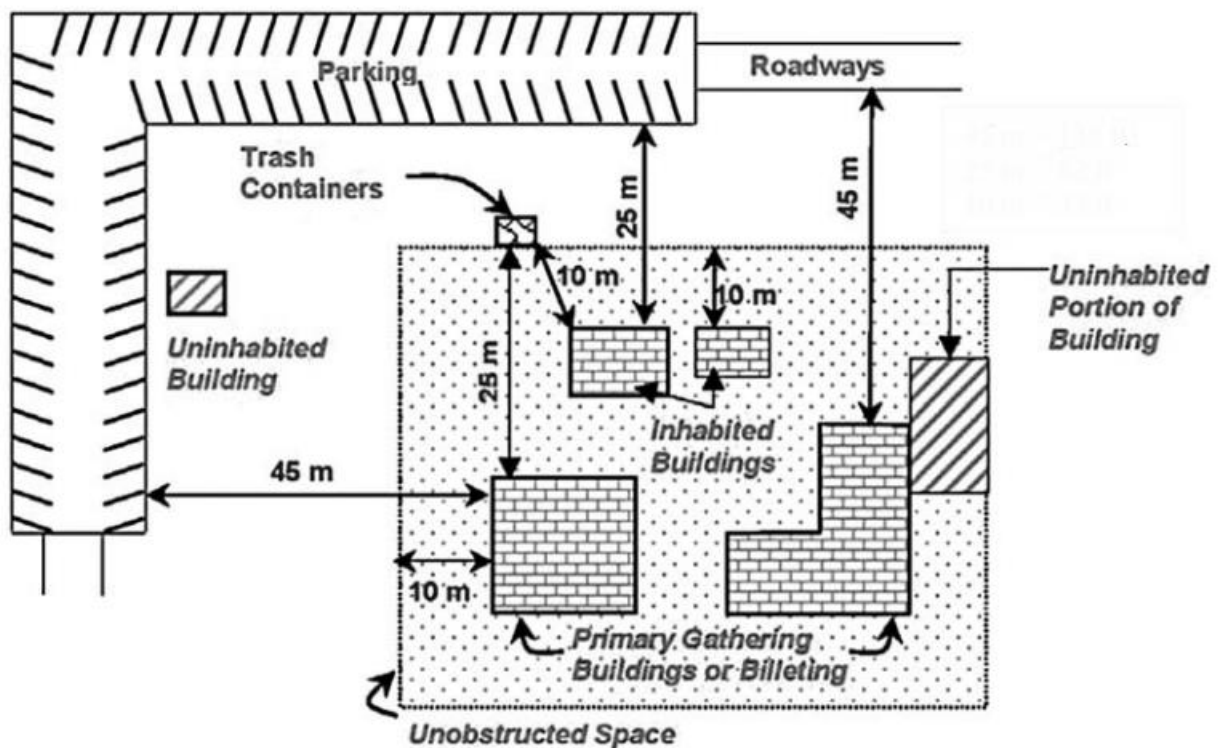
The most cost effective solution for mitigating explosive effects is to ensure the explosions occur as far away from the building as possible (**increased standoff**).



Therefore, site selection for new construction and site protection in existing structures is important in mitigation blast risk.



Minimum Standoffs for Buildings of Conventional Construction with a Controlled Perimeter according to DoD 2007a[1] specifications



Minimum Standoffs for Buildings of Conventional Construction Without a Controlled Perimeter according to DoD 2007a[1] specifications

****Use of Protective Barriers Walls**

Many types of barriers are designed to resist the impact of a vehicle bomb. Among them are massive concrete barriers (Kontek 2008[2]), concrete enclosed with steel plates (Crawford and Lan 2006[3]), and soil filled corrugated metal (Crawford and Lan 2006[3]). Pictures of a few representative barriers are shown in the following figure. Each barrier is designed to absorb the large amounts of energy from an impact or blast with minimal effect on the facilities it is protecting.

**(a) massive
concrete barriers**



(a)

**(b) concrete enclosed
in steel plates barriers**



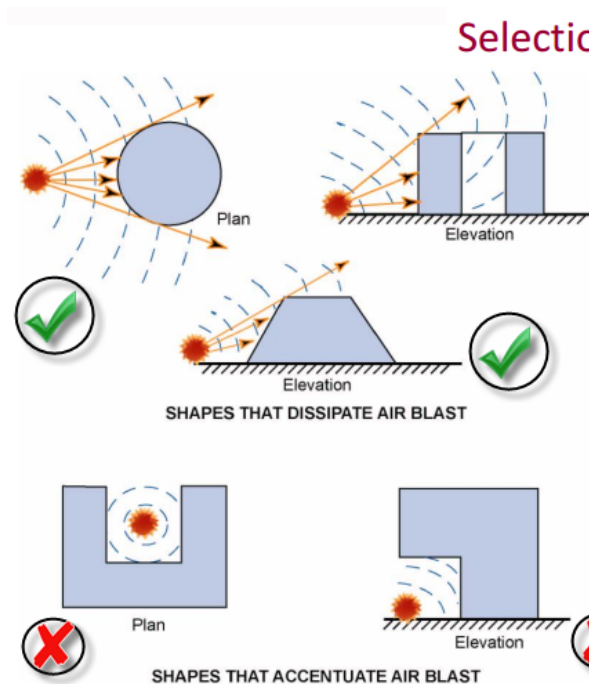
(b)



(c)

**(c) soil filled corrugated
metal barriers**

**Proper Selection of Building Layout



Selection of Building Layout

The building shape and layout should be selected to minimize the effects of blast loading. Re-entrant corners and overhangs are likely to trap shock wave and amplify the effect of blast. The reflected pressure on the surface of a circular building is less intense than on a flat building. When curved surfaces are used, convex shapes are preferred over concave shapes.



**Desirable Structural Forms

○

Arches



○

Domes



○

Single Story Buildings



****Undesirable Structural Forms**

*Complex Shapes



*Projecting Roofs or Floors



*U-Shaped Building



*Multistory Buildings



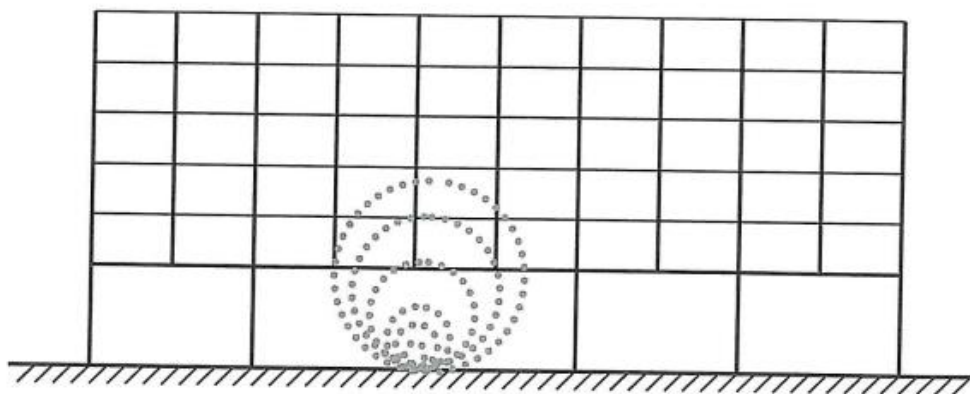
FEMA 427[4]-Recommendations:

- *Use simple geometries without sharp re-entrant corners
- *Place the building on the site as far from the perimeter as practical.

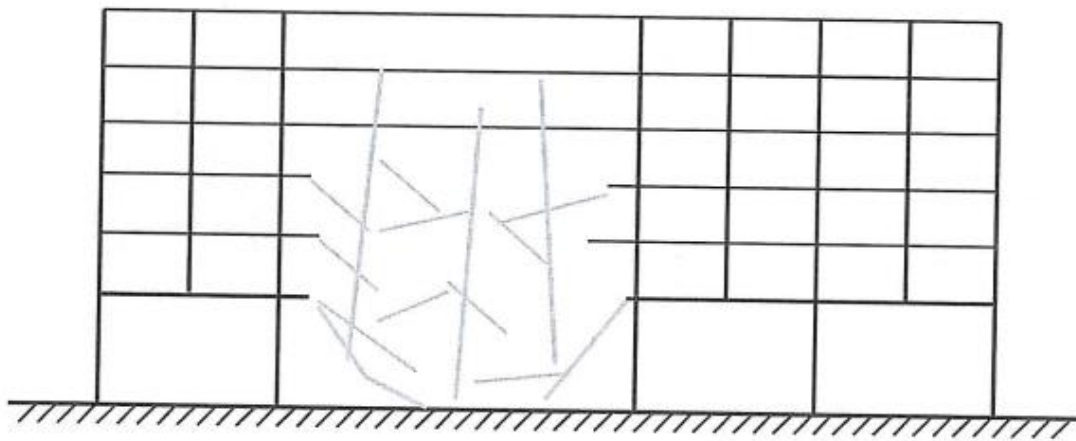
**Proper Selection of Structural System According to FEMA 427 [4]Guidelines

1. Frame System

- ☐ In frame structures, column spacing should be limited. Large column spacing decreases likelihood that the structure will be able to redistribute load in event of column failure.
- ☐ In frame structures, the exterior columns should be designed to resist the direct effects of the specified blast.
- ☐ The frame structures system should be designed to resist the likely progressive collapse. In case of occurrence any localized failure.
- ☐ It should not to Use of **TRANSFER GIRDERS**. Loss of a transfer girder or one of its supports can destabilize a significant area of the building. If the transfer girders are required, it must be to add extra transfer systems, as shown in the following figures.



Detonation and destruction of one main column



Failure of the transfer girder and secondary columns

*Bearing-Wall Systems

- ❑ In bearing-wall systems that rely primarily on interior cross-walls, interior longitudinal walls should be spaced to enhance stability and to control the lateral progression of damage.
- ❑ In bearing-wall systems that rely on exterior walls, perpendicular walls should be provided at a regular spacing to control the amount of wall that is likely to be affected.

2. Roof System

The primary loading on the roof is the downward air-blast pressure.

- ❑ The preferred system is cast-in place reinforced concrete with beams in two directions.
- ❑ If this system is used, beams should have continuous top and bottom reinforcement with tension lap splices.
- ❑ Stirrups to develop the bending capacity of the beams closely spaced along the entire span are recommended.
- ❑ Use two-way floor and roof systems

**Proper Selection of Structural Material

Which Building Materials are Preferred?

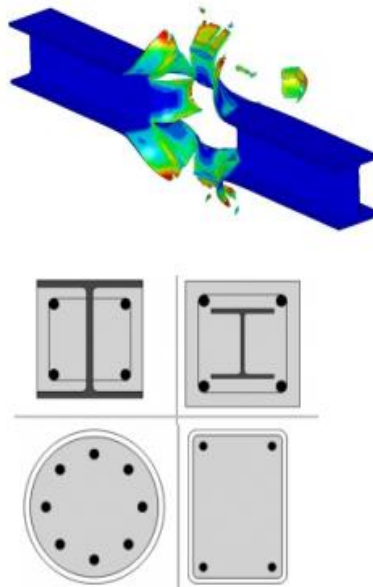
- ❑ Cast-in-place reinforced concrete is the structural system preferred for blast-resistant construction. This is the material and structural type used for military bunkers. The military has performed extensive research and testing of its performance. Concrete has significant mass, which improves response to explosions.
- ❑ Generally, simple geometries and minimal ornamentation (which may become flying debris during an explosion) are recommended. If ornamentation is used, it is preferable to use *lightweight materials such as timber or plastic*, which are less likely than brick, stone, or metal to become lethal projectiles in the event of an explosion.

❑ Ultra High Performance Concrete (UHPC)

UHPC is known for its superior mechanical properties; compressive strength can reach up to 200 MPa and tensile strength up to 40 MPa. Also, the crack propagation can be well controlled due to inclusion of steel fibres in its cement matrix, leading to a higher ductility and energy absorbing capacity so as to make it an ideal material for structural members that are exposed to the constant threat of blast attacks. Previous experimental work conducted by Mao et al., Wu et al.[5], Barnett et al.,[6], Ibrahim Metwally[7] , Schleyer et al.[8], and Melançon[9] confirmed the superior blast resistance of UHPC structures under high loading rate conditions such as explosion and impact compared to traditional normal & high strength concrete.

**Increase the Capacity of the Ground Floor Columns

Concrete-filled steel columns have the high ductility and the very good blast resistance [Peyman, Et al. [10], Ibrahim Metwally,[7] and Zhang, et al. [11]



Concrete systems have significant inertia but are susceptible to shear failures.

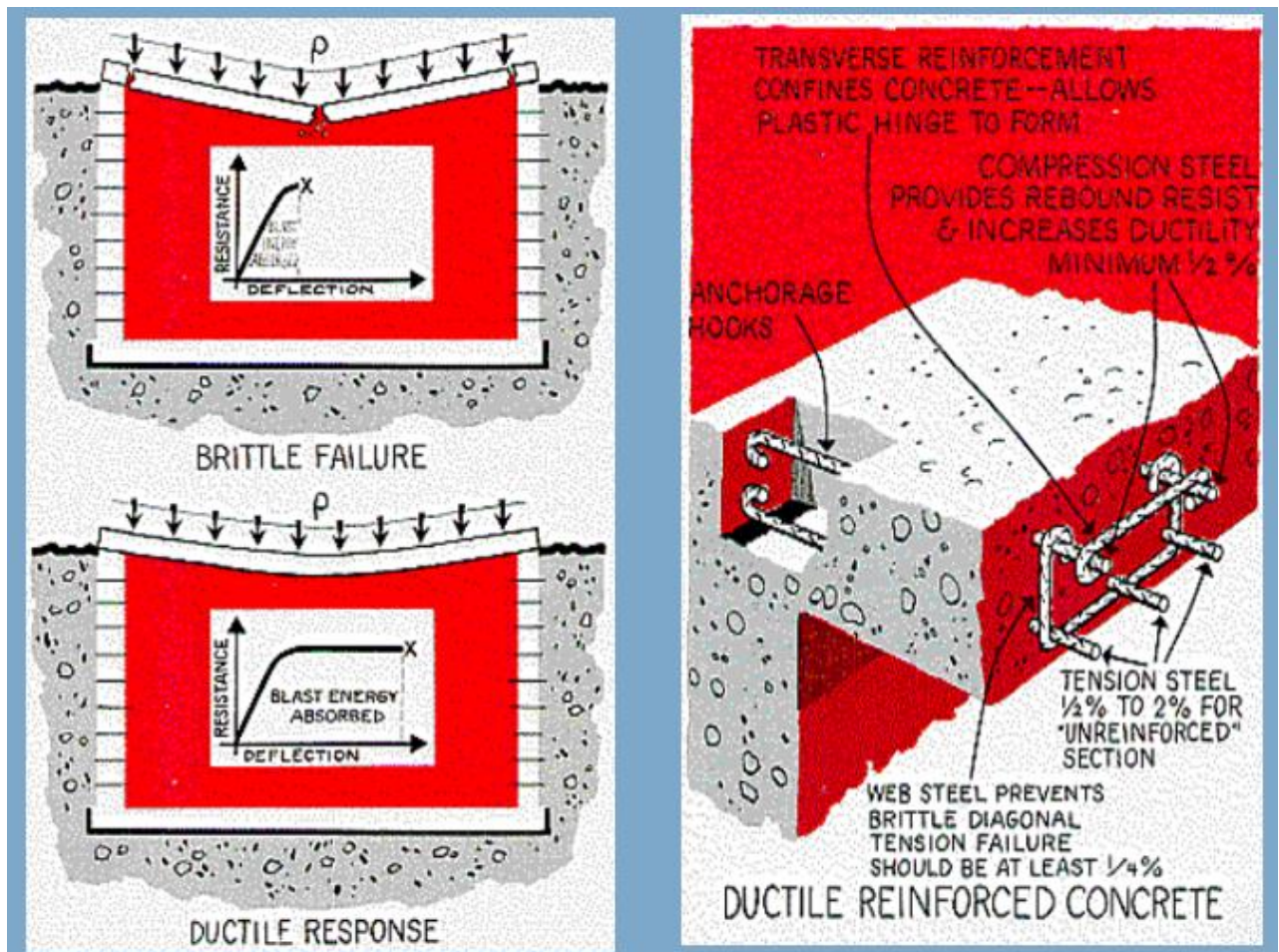
Steel systems have inherent ductility but are locally vulnerable open sections and connections.

Combination of steel and concrete is ideal.

**Ductile Structural Elements

Ductile detailing of reinforcements

- *Blast-resistant design philosophy allows structural elements to undergo large inelastic (plastic) deformations under blast loading.
- *A ductile structure that undergoes large deformations without failure can absorb much more energy than a brittle structure of the same strength
- *Tensile reinforcement between 0.5 and 2 % of the cross-sectional area of the concrete element will usually ensure ductile behavior while providing the required strength.
- *Compression steel in flexural members serves two purposes. After a structural member is deflected by blast loads, it attempts to spring back or rebound. *Dynamic rebound causes load reversal and, under certain conditions, can result in catastrophic failure.*



Acceptable Damage Levels

Minor: Non-structural failure of building elements as windows, doors, and cladding.

Moderate: Structural damage is confined to a localized area and is usually repairable. Structural failure is limited to secondary structural members, such as beams, slabs and non-load bearing walls. However, if the building has been designed for loss of primary members, localized loss of columns may happen without initiating progressive collapse.

Major: Loss of primary structural components such as columns or transfer girders leads to loss of additional adjacent members that are adjacent or above the lost member. In this case, the building is usually not repairable.

1.3 Prevent Progressive Collapse & Catastrophic Failure

The aim of blast resistant building design is to:

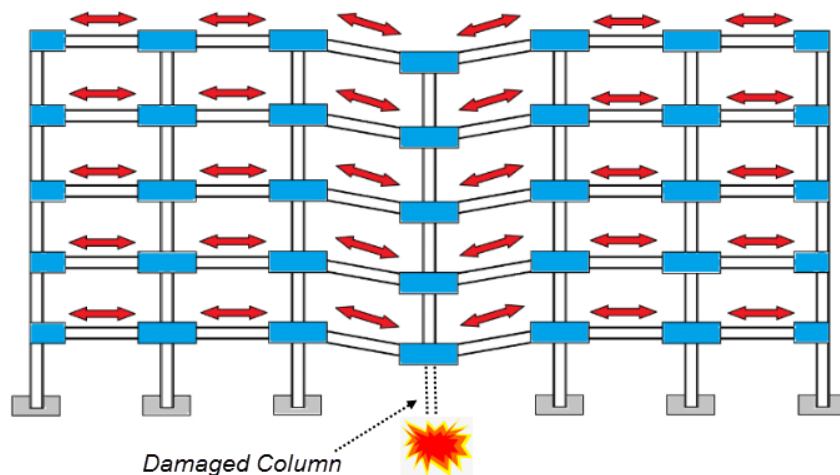
- *Evaluation of the potential progressive collapse in new and existing buildings*
- *Prevent the overall collapse of the building and fatal damages.*

How to Prevent Progressive Collapse???

1- Alternate Load Path Method

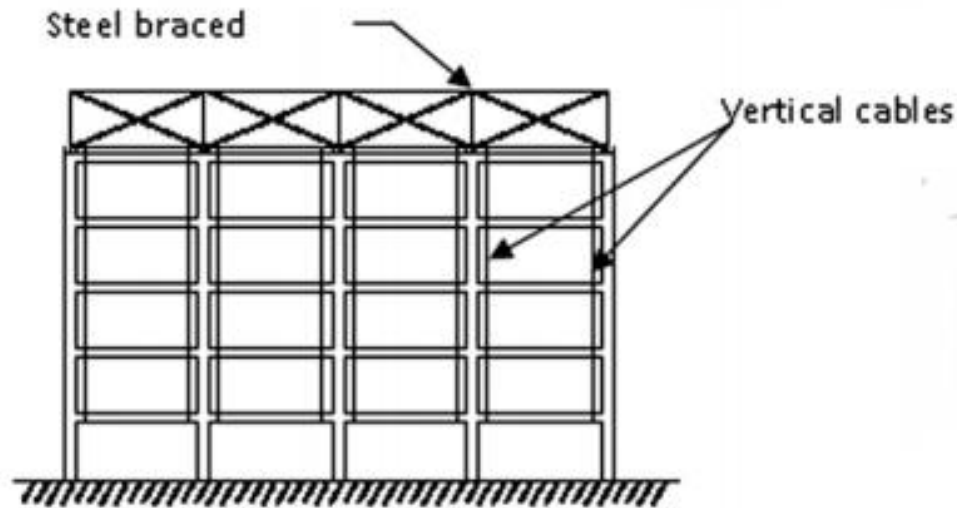
This method is mainly recommended by the Department of Defense (DoD, 2007[1]) and General Services Administration (GSA, 2003[12]).

The philosophy of this method is to permit the occurrence of the local damage; however, the collapse of large portion of the structure is avoided by providing alternate load paths in the neighboring elements to redistribute the loads that were applied on the damaged components if they have designed sufficiently

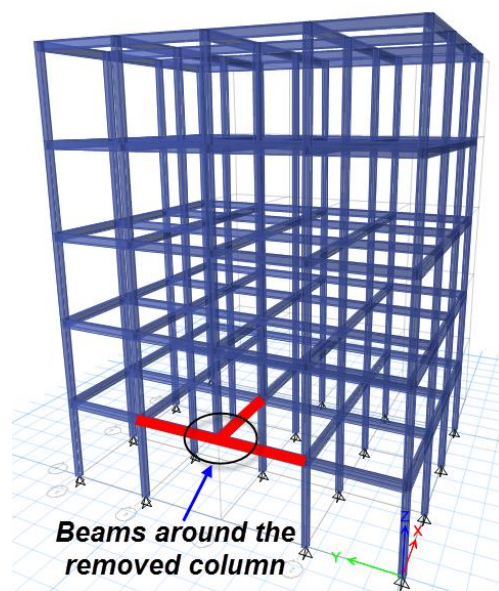


Besides, In the recent published research works, there are several ways to prevent progressive collapse as:

- 2- by embedding vertical steel cables in columns and hanging them at the top to a hat braced frame placed on the top of the building which is seated on the top of the columns.(Hadi & Al-Rudaini[13])

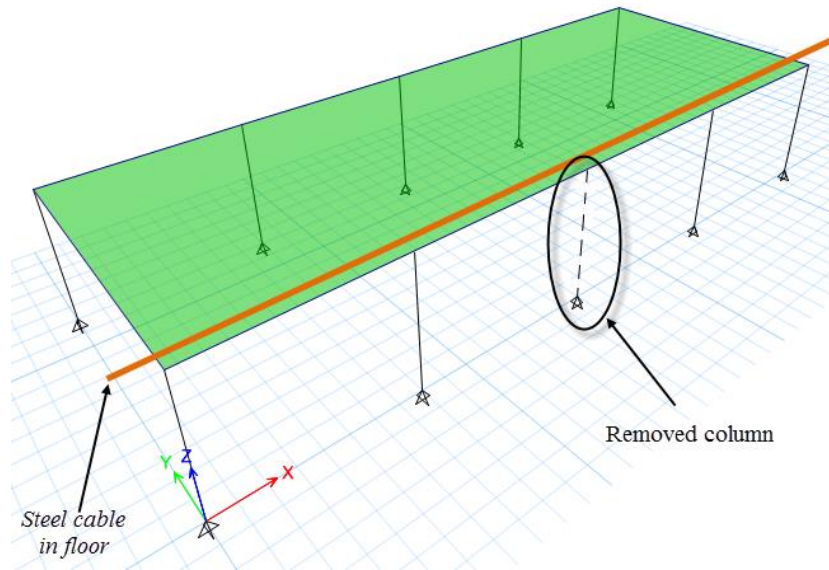


3- Progressive collapse can be avoided for steel and RC structures if the depth of the beams around the removed column MORE than $\text{span}/15$ and $\text{span}/12$ respectively. (Izadifard, 2014, [14])



4- ASL [15] investigated a new way to prevent progressive collapse of floors, by placing steel cables inside the concrete floor slabs for new construction or adding the cables under the slab for existing structures as a measure of retrofit. The main role of these cables is to prevent progressive collapse of the floor in the event of loss of one of the columns.

The following figure shows the application of this concept in a building. When a single column is removed and the floor starts to collapse, the steel cable prevents the collapse and transfers the load of the floor to neighboring columns and rest of the structures. Since cables are used in every floor, the loads of all floors above the removed column will be transferred to the adjacent columns. As a result, although the floors might have relatively large deformations in the order of 40-60 centimeters, the full progressive collapse and pan-caking of the floors are prevented.



****DAMAGE EVALUATION FORMS**
for Building Subjected to Blast loading

Norazman et al. [16] suggested the use of damage evaluation form in evaluating damaged structures due to various reasons such as acts of terrorism. This form is effective and gives a detailed inspection view and could be used as a guide for decision making and planning for rehabilitation work.

15

Location1:

SECTION 4		DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level:		Location:	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
	Weightage	None	Repair	Protective Support	Remove
Load Bearing wall	☐	☐	☐	☐	☐
Column	☐	☐	☐	☐	☐
Beam	☐	☐	☐	☐	☐
Staircase	☐	☐	☐	☐	☐
Slab	☐	☐	☐	☐	☐
Roof Structure	☐	☐	☐	☐	☐
Weightage :-		Total: _____			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

SECTION 5		DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level:		Location:	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
	Weightage	None	Repair	Protective Support	Remove
Interior Wall	☐	☐	☐	☐	☐
Exterior Wall	☐	☐	☐	☐	☐
Partitions	☐	☐	☐	☐	☐
Electrical system	☐	☐	☐	☐	☐
Plumbing System	☐	☐	☐	☐	☐
Weightage :-		Total: _____			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

Note: Section 4 and Section 5 to be repeated for every location assessed.

Location2:

SECTION 4		DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level:		Location:	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
	Weightage	None	Repair	Protective Support	Remove
Load Bearing wall	☐	☐	☐	☐	☐
Column	☐	☐	☐	☐	☐
Beam	☐	☐	☐	☐	☐
Staircase	☐	☐	☐	☐	☐
Slab	☐	☐	☐	☐	☐
Roof Structure	☐	☐	☐	☐	☐
Weightage :-		Total: _____			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

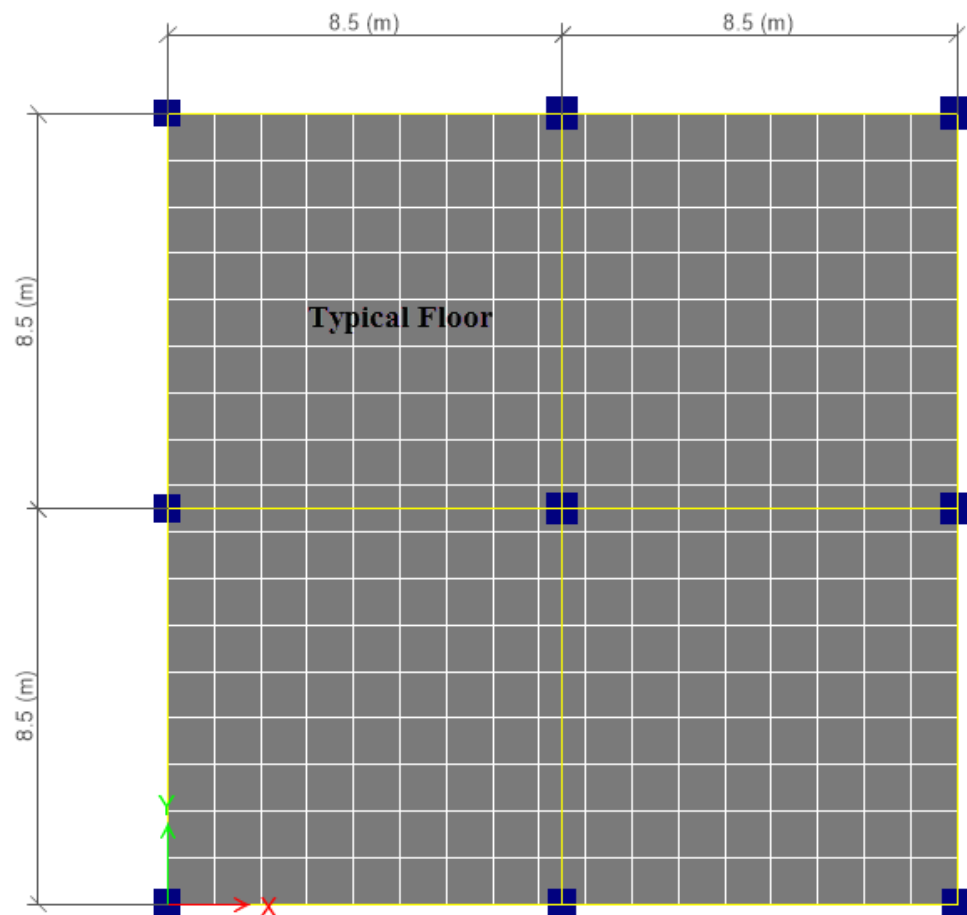
SECTION 5		DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level:		Location:	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
	Weightage	None	Repair	Protective Support	Remove
Interior Wall	☐	☐	☐	☐	☐
Exterior Wall	☐	☐	☐	☐	☐
Partitions	☐	☐	☐	☐	☐
Electrical system	☐	☐	☐	☐	☐
Plumbing System	☐	☐	☐	☐	☐
Weightage :-		Total: _____			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

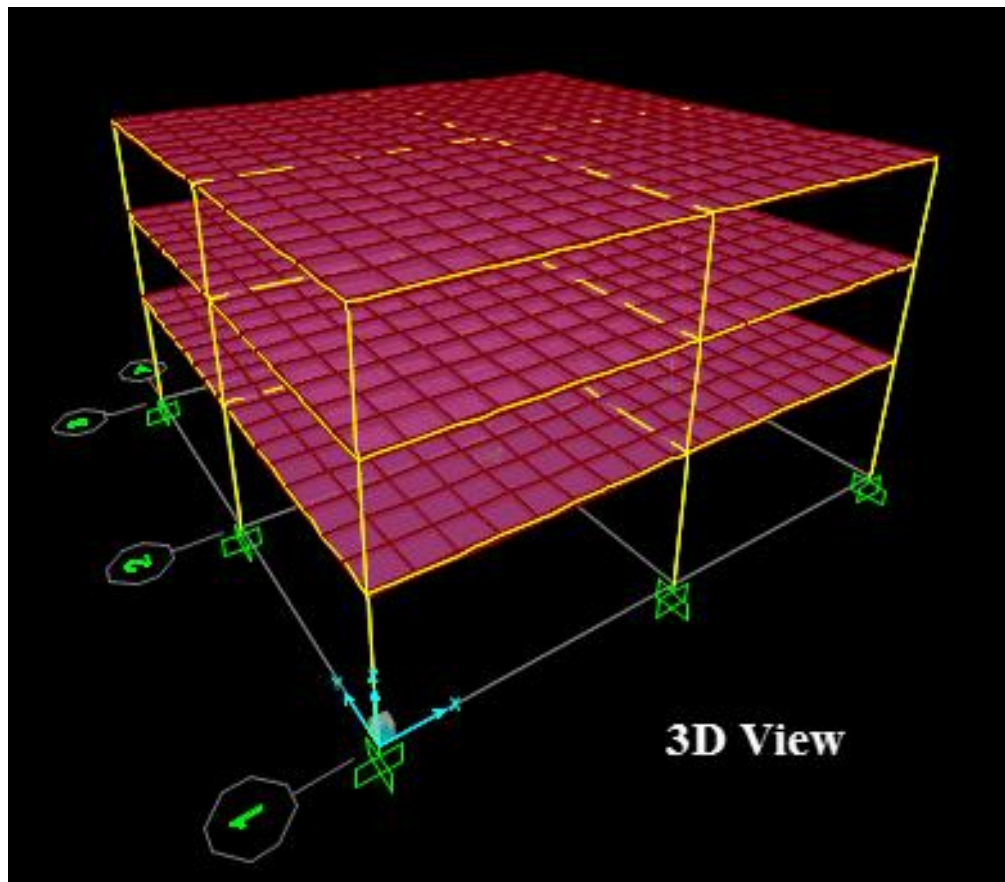
Note: Section 4 and Section 5 to be repeated for every location assessed.

SECTION 6 DAMAGE CLASSIFICATION														
Total Weightage (Section 4 & 5) = _____		Total Location Assessed = _____												
$\text{Damage Index} = \frac{\text{Total Weightage} \times \text{Total Location Assessed}}{\text{Total Location} \times 11 \text{ (criteria)}}$														
Damage Index = _____														
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: center;">Damage Index</th> <th style="text-align: center;">Damage Classification</th> <th style="text-align: center;">Building Usage</th> </tr> <tr> <td style="text-align: center;">> 3</td> <td style="text-align: center; background-color: red;">Red</td> <td style="text-align: center;">Unsafe</td> </tr> <tr> <td style="text-align: center;">2 - 3</td> <td style="text-align: center; background-color: yellow;">Yellow</td> <td style="text-align: center;">Limited</td> </tr> <tr> <td style="text-align: center;">< 2</td> <td style="text-align: center; background-color: green;">Green</td> <td style="text-align: center;">Safe</td> </tr> </table>	Damage Index	Damage Classification	Building Usage	> 3	Red	Unsafe	2 - 3	Yellow	Limited	< 2	Green	Safe		
Damage Index	Damage Classification	Building Usage												
> 3	Red	Unsafe												
2 - 3	Yellow	Limited												
< 2	Green	Safe												
SECTION 7 EMERGENCY ACTION FOR THE WHOLE BUILDING														
Emergency Action ☐ Minor repair ☐ Remove hazardous materials from building ☐ Protect building from progressive collapse ☐ Immediate Demolition														
SECTION 8 EQUIPMENT UTILISED FOR DAMAGE ASSESSMENT														
Damage Assessment Tools ☐ Schmidt Rebound Hammer ☐ Pundit Test ☐ Electromagnetic Cover Meter ☐ Sound Wave Hammer ☐ Core Test ☐ Other Test: _____														
SECTION 9 INSPECTORS SUMMARY														
1. Ground Condition :														
2. Structural Condition :														
3. Propose Rehabilitation :														
4. Other Comment :														
Completion Time: _____		Date: _____												
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="3" style="text-align: center;">Verified by</td> </tr> <tr> <td style="text-align: center;">Head of Team</td> <td style="text-align: center;">Team Member 1</td> <td style="text-align: center;">Team Member 2</td> </tr> <tr> <td style="height: 40px;"></td> <td></td> <td></td> </tr> </table>			Verified by			Head of Team	Team Member 1	Team Member 2						
Verified by														
Head of Team	Team Member 1	Team Member 2												

EXAMPLE APPLICATION:

Evaluation of blast-damaged concrete building according to GSA guidelines.





Gravity Loads were taken as:-

Covering = 0.15 t/m²

Walls = 1.35 t/m acting on beams

LL= 0.3 t/m²

Dimensions & Reinforcements of Beams & Columns in the following table.

Dimensions and reinforcement of edge beams and typical columns in Model 1 at the ground floor level designed according to ACI 318-05.

		Dimensions (in. × in.)	Reinforcement (in. ²)
Edge Beam Spans	Exterior	14 × 24	2.58 (Top) 1.24 (Bottom)
	Interior	14 × 22	2.37 (Top) 1.14 (Bottom)
Columns	Corner	22 × 22	4.84
	Exterior	22 × 22	8.75
	Interior	26 × 26	30.87

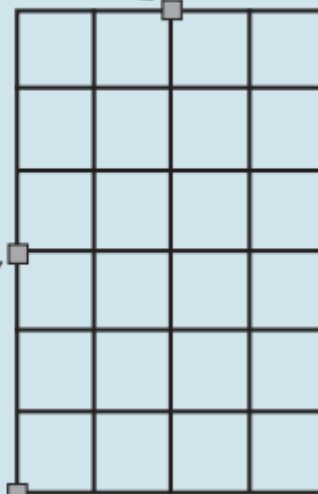
The GSA [12] recommendations state the following scenarios:

1. Remove a load bearing element (column) near or at the middle of a longer side.
2. Remove a load bearing element near or at the middle of a shorter side.
3. Remove a load bearing element at the corner (This scenario was selected in this example)

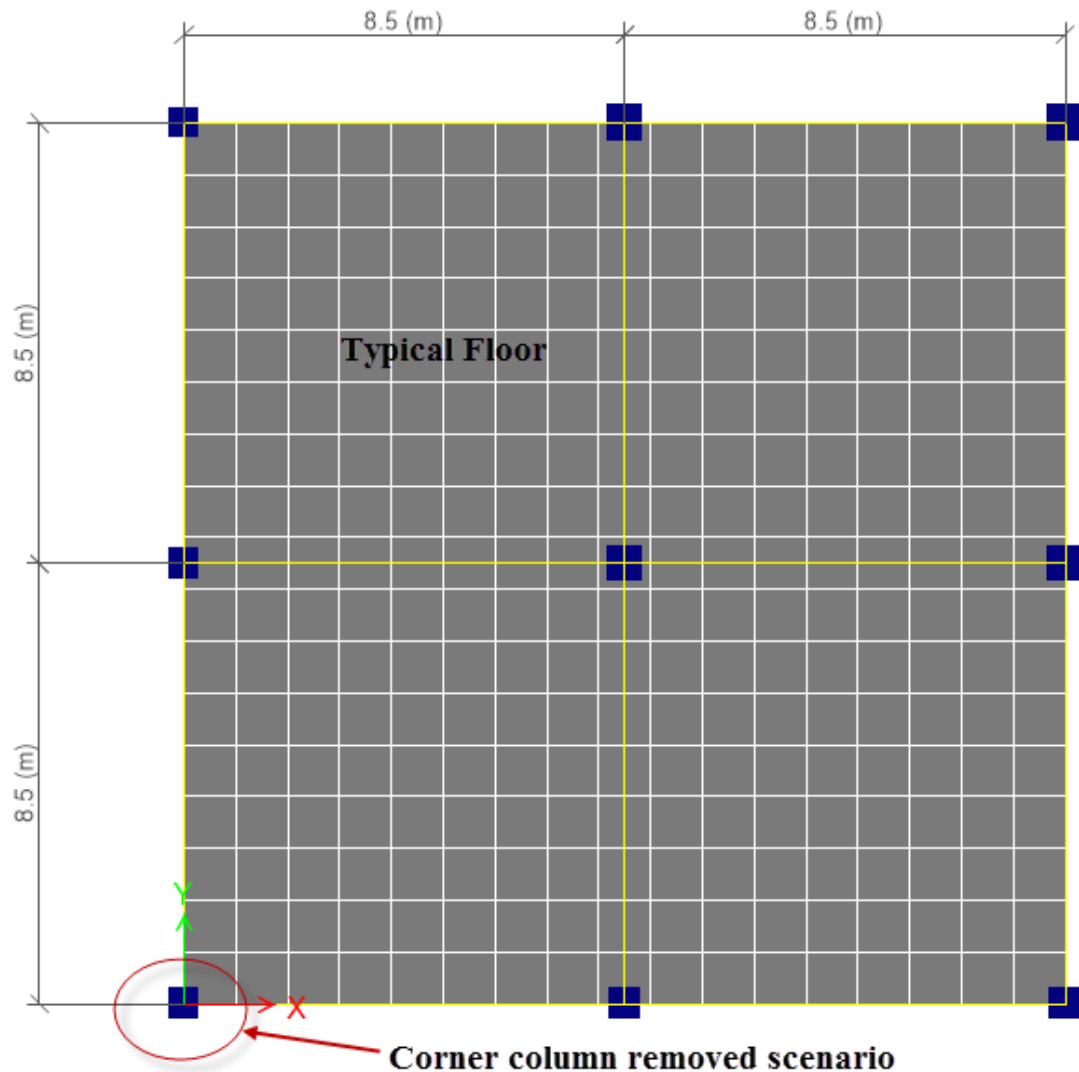
1 Analyze for the instantaneous loss of a column for one floor above grade (1st story) located near the middle of the short side of the building.

2 Analyze for the instantaneous loss of a column for one floor above grade (1st story) located near the middle of the long side of the building.

3 Analyze for the instantaneous loss of a column for one floor above grade (1st story) located at the corner of the building.



Plan View



Steps of Nonlinear Dynamic Analysis According to GSA Guidelines

The nonlinear dynamic collapse analysis is needed to observe the formulation of plastic hinges through the structure, and the failed elements.

Step 1: Prepare three dimensional model in computer. Perform concrete design and determine the reinforcement to be provided in members.

Step 2: Define and assign plastic hinges to beams(at both ends , at 0.5 of span , at 0.3 of span & at 0.7 of span) and columns(at both ends).

Step 3: All loads to be used in this analysis as per the load combinations $DL+0.25LL$ defined in GSA guidelines, where DL is the dead loads and LL is the live loads **and define non-linear dynamic case.**

Step 4: SAP2000 V. 21[17] can do *dynamic collapse analysis* to model progressive collapse. Nonlinear dynamic analysis case for column removal has been defined in SAP2000 as shown in the following figure.

Load Case Data - Nonlinear Direct Integration History

Load Case Name

ProgCol

Set Def Name

Notes

Modify/Show...

Load Case Type

Time History

Design...

Initial Conditions

☒ Zero Initial Conditions - Start from Unstressed State

☐ Continue from State at End of Nonlinear Case

Important Note:

Loads from this previous case are included in the current case

Modal Load Case

Use Modes from Case

MODAL

Objects to Remove

Object Type	Object Name	Removal Time	Duration
Frame	1535	0.047	0.0047
Frame	1535	0.047	0.0047

Add

Modify

Delete

Sort

Sort and Make Durations Consistent

☒ Show Objects to Remove

Time Step Data

Number of Output Time Steps

10000

Output Time Step Size

5.000E-03

Other Parameters

Damping

Proportional

Modify/Show...

Time Integration

Hilber-Hughes-Taylor

Modify/Show...

Nonlinear Parameters

Default

Modify/Show...

Analysis Type

☐ Linear
 ☒ Nonlinear

Solution Type

☐ Modal
 ☒ Direct Integration

Geometric Nonlinearity Parameters

☐ None
 ☒ P-Delta
 ☐ P-Delta plus Large Displacements

History Type

☒ Transient
 ☐ Periodic

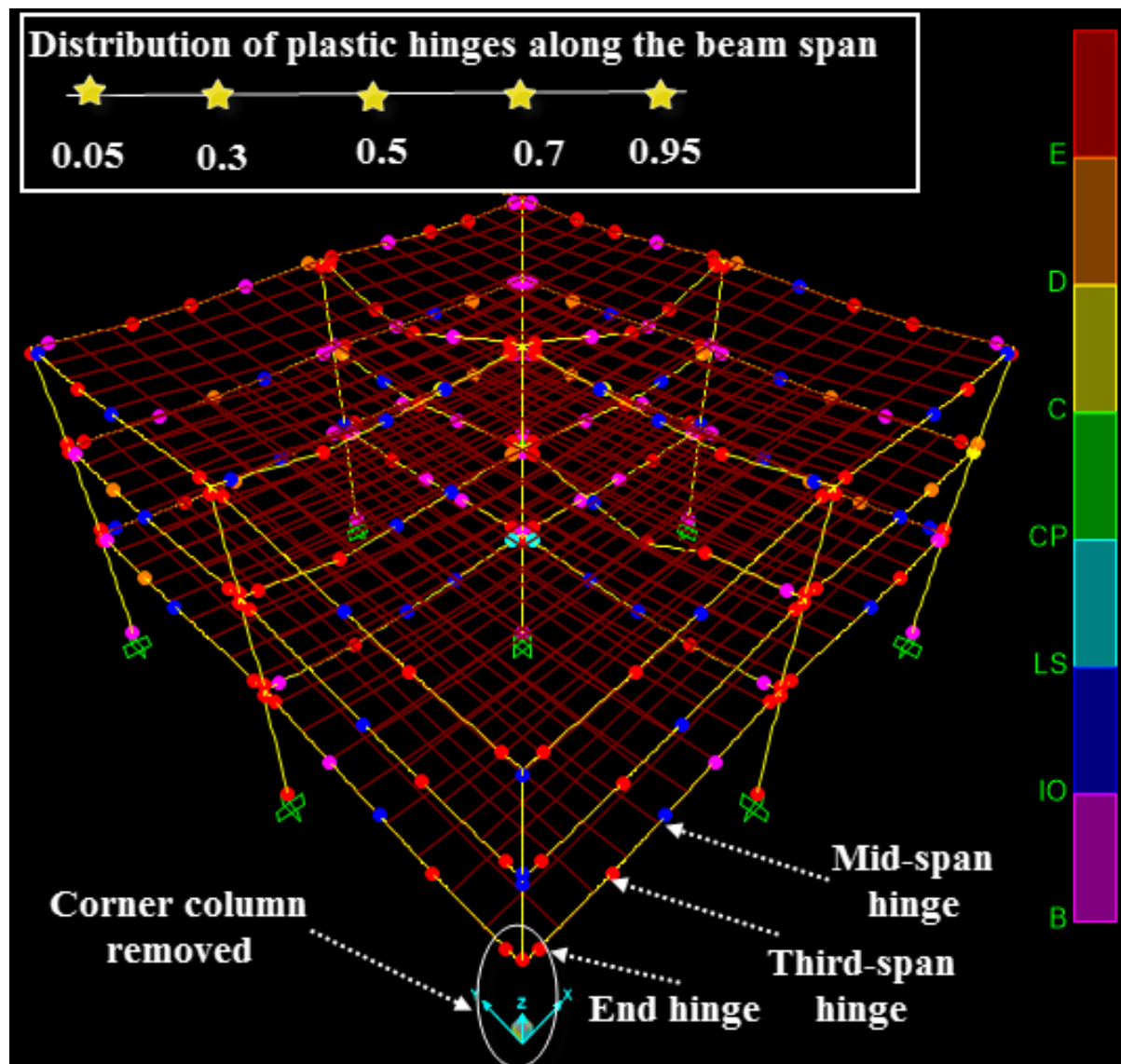
Mass Source

MSSSRC1

OK

Cancel

Step 5: Observe the hinge formation status for all frame members at failure.



Appearance of Plastic hinges in beams & columns

Damage Limits: According to FEMA-356[18], when the plastic hinge rotations are more than 0.025 radians for any member, it is considered as COLLAPSED (beyond the CP, collapse prevention state.). Also, according to Egyptian Specifications for Blast-Resistant buildings[19], that the permissible damage area due to the loss of an external column must be smaller of 70 m², (the damaged area of the slab panel above the removed column equal $8.5 \times 8.5 = 72 \text{ m}^2$)

Summary & Recommendations: The plastic hinges are spread in all beams and columns as shown in above figure. Value of most plastic hinge rotations for most members for this scenario are bigger than 0.025, hence, collapse will occur. Consequently, overall progressive collapse is expected for this structure.

Application of Damage Evaluation Forms for This Case

Location 1

SECTION 4		DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>ground</u>		Location: <u>removed column side</u>	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Load Bearing wall	☐	☐	☐	☐	☐
Column	☒	☐	☐	☐	☒
Beam	☒	☐	☐	☐	☒
Staircase	☐	☐	☐	☐	☐
Slab	☒	☐	☐	☐	☒
Roof Structure	☐	☐	☐	☐	☐
Weightage :-	Total: <u>12</u>				
1 = None 2 = Light 3 = Moderate 4 = Serious					
SECTION 5		DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>ground</u>		Location: <u>removed column side</u>	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Interior Wall	☒	☐	☐	☐	☒
Exterior Wall	☒	☐	☐	☐	☒
Partitions	☒	☐	☐	☐	☒
Electrical system	☒	☐	☐	☐	☒
Plumbing System	☒	☐	☐	☐	☒
Weightage :-	Total: <u>20</u>				
1 = None 2 = Light 3 = Moderate 4 = Serious					

Location2:

SECTION 4		DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>first floor</u>		Location: <u>removed column side</u>	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Load Bearing wall	☐	☐	☐	☐	☐
Column	☐	☐	☐	☒	☐
Beam	☐	☐	☐	☒	☐
Staircase	☐	☐	☐	☐	☐
Slab	☐	☐	☐	☒	☐
Roof Structure	☐	☐	☐	☐	☐
Weightage :-		Total: <u>12</u>			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

SECTION 5		DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>first floor</u>		Location: <u>removed column side</u>	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Interior Wall	☐	☐	☐	☐	☒
Exterior Wall	☐	☐	☐	☐	☒
Partitions	☐	☐	☐	☐	☒
Electrical system	☐	☐	☐	☒	☐
Plumbing System	☐	☐	☐	☒	☐
Weightage :-		Total: <u>18</u>			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

Location 3

SECTION 4		DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>second floor</u>		Location: <u>removed column side</u>	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Load Bearing wall	☐	☐	☐	☐	☐
Column	☐	☐	☐	☒	☐
Beam	☐	☐	☐	☒	☐
Staircase	☐	☐	☐	☐	☐
Slab	☐	☐	☐	☒	☐
Roof Structure	☐	☐	☐	☐	☐
Weightage :-		Total: <u>11</u>			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

SECTION 5		DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES			
		Level: <u>second floor</u>		Location: <u>removed column side</u>	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Interior Wall	☐	☐	☐	☐	☒
Exterior Wall	☐	☐	☐	☐	☒
Partitions	☐	☐	☐	☐	☒
Electrical system	☐	☐	☐	☒	☐
Plumbing System	☐	☐	☐	☒	☐
Weightage :-		Total: <u>18</u>			
		1 = None 2 = Light 3 = Moderate 4 = Serious			

Location similar locations

SECTION 4 DAMAGE TO STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES					
		Level:		Location:	
Damage level and extension Structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Load Bearing wall	☐ 4	☐	☐	☐	☐
Column	☐ 4	☐	☐	☐	☐
Beam	☐ 4	☐	☐	☐	☐
Staircase	☐ 3	☐	☐	☐	☐
Slab	☐ 3	☐	☐	☐	☐
Roof Structure	☐	☐	☐	☐	☐
Weightage :-	Total: 11				
1 = None 2 = Light 3 = Moderate 4 = Serious					

SECTION 5 DAMAGE TO NON-STRUCTURAL ELEMENT AND THE EMERGENCY MEASURES					
		Level:		Location:	
Damage level and extension Non-structural component	Extend of Damages	Emergency measures			
		None	Repair	Protective Support	Remove
	Weightage				
Interior Wall	☐ 3	☐	☐	☐	☐
Exterior Wall	☐ 3	☐	☐	☐	☐
Partitions	☐ 3	☐	☐	☐	☐
Electrical system	☐ 2	☐	☐	☐	☐
Plumbing System	☐ 2	☐	☐	☐	☐
Weightage :-	Total: 13				
1 = None 2 = Light 3 = Moderate 4 = Serious					

Damage Evaluation Procedure for Building Subjected to Blast Impact

SECTION 6 DAMAGE CLASSIFICATION			
Total Weightage (Section 4 & 5) = 307		Total Location Assessed = 12	
$\text{Damage Index} = \frac{\text{Total Weightage} \times \text{Total Location Assessed}}{\text{Total Location} \times 11 \text{ (criteria)}}$		$= \frac{307 \times 12}{12 \times 11}$	
Damage Index = 27.9			
Damage Index	Damage Classification	Building Usage	
> 3	Red	Unsafe	
2 - 3	Yellow	Limited	
< 2	Green	Safe	

SECTION 7 EMERGENCY ACTION FOR THE WHOLE BUILDING	
Emergency Action	
☐	Minor repair
☐	Remove hazardous materials from building
☐	Protect building from progressive collapse
☒	Immediate Demolition

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Analysis & Assessment of Buildings Subjected to Blast Loads - Quiz

Updated: 7/24/2024

1. To reduce blast demands, it must be
 - a. Increase standoff distance
 - b. Increase compressive strength of concrete
 - c. Increase tensile strength of concrete
 - d. Increase durability of concrete

2. To reduce blast demands, it must be
 - a. Use lightweight concrete
 - b. Use of Protective Barriers Walls
 - c. Use heavy weight concrete
 - d. Use high strength concrete

3. Use simple geometries without sharp re-entrant corners
 - a. For blast-resistance buildings
 - b. For seismic resistance buildings
 - c. For fire resistance buildings
 - d. For impact resistance buildings

4. It should not to Use of TRANSFER GIRDERS for building exposed to
 - a. Static loading
 - b. Gravity loading
 - c. Blast loading.
 - d. Seismic loading

5. It should be used two-way floor slab in concrete building
- a. Seismic loading
 - b. Gravity loading
 - c. Static loading
 - d. Exposed to blast loading
6. Cast-in-place reinforced concrete is the structural system preferred for blast-resistant construction. This statement is
- a. TRUE
 - b. I do not know
 - c. False
 - d. Not true
7. Ultra high performance concrete has superior behavior under
- a. Gravity loading
 - b. Dynamic loading
 - c. Explosion and impact
 - d. Static loading
8. Blast-resistant design philosophy allows structural elements to undergo
- a. Large strain
 - b. Large deflections
 - c. Large stresses
 - d. Large inelastic (plastic) deformations under blast loading.
9. What is the Tensile reinforcement which insure ductile behavior under blast loading
- a. From 0.5 and 2 % of the cross-sectional area of the concrete element
 - b. 12%
 - c. 8%
 - d. 6%

10. Alternate Load Path Method used for
- a. Prevent progressive collapse
 - b. Design of concrete buildings
 - c. Analysis of steel structures
 - d. Analysis of timber buildings
11. The accurate way to do progressive collapse analysis is
- a. By nonlinear dynamic analysis
 - b. By linear dynamic analysis
 - c. By linear static analysis
 - d. By nonlinear static analysis
12. The load combination used in nonlinear dynamic analysis as specified in GSA guidelines is
- a. DL+LL
 - b. DL
 - c. DL+0.25LL
 - d. DL+ Wind
13. Nonlinear dynamic collapse analysis now can be done by
- a. SAP 2000 version 21
 - b. ETABS
 - c. SAP 2000 version 10
 - d. Csi Safe
14. According to FEMA-356, the member will collapse if the plastic hinge rotations are more than
- a. 0.2 radians
 - b. 0.5 radians
 - c. 0.25 radians
 - d. 0.025 radians

15. According to Egyptian Specifications for Blast-Resistant buildings , that the permissible damage area due to the loss of an external column must be smaller of
- a. 65 m²
 - b. 70 m²
 - c. 77 m²
 - d. 71 m²