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Architectural Approach toward Protecting Structures against Nuclear Explosion Threats and Hazards

By

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Abstract:

Despite the presence of many international proposals and treaties to limit and reduce nuclear weapons testing and stockpiling, still there are a number of countries that insist on having such kind of weapons. The threat of using nuclear weapon in a planned attack or in a terrorist attack is a matter that has to be taken in consideration in order to avoid or at least minimize its consequences. Hiroshima and Nagasaki images are still in memories, as the only historical cases in which the nuclear weapon was used. The nuclear tests are still ongoing, alerting that "there should be a counter action towards protection against the development of nuclear weapons" to avoid the recurrence of Hiroshima and Nagasaki disasters.

This paper spotlights the physical effects of the nuclear weapon nature, evaluating the damages caused to structures and architectural elements exposed to nuclear detonations. It introduces some precautions that assist in improving the architectural design process, and hence improve the protection level against the nuclear threat.

Keywords: Nuclear threats, Nuclear hazards, Architectural design.

1. Introduction

In general, the unstable international political state, the unbalanced power levels around the world and the conflicts between countries or indicate a high probability of using nuclear weapons, especially as many countries nowadays already own the weapon. The use of nuclear weapon is an action that threatens the national security of many countries, and the reaction which is protection can be achieved by applying studies that come out with suitable solutions

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and protection ideas for structures, especially important structures that affect the national security of the country.

From here the scope of this study is focused on the following points:

1- Spotlight the physical feelings and the nature of the nuclear weapon.
2- Evaluating the damages that are caused to structures exposed to a nuclear detonation.
3- Evaluating the damages of the architectural elements when exposed to a nuclear detonation.
4- Evaluating our immediate technological capability to deal with the nuclear threat.
5- Finding out how to improve the architectural design toward protection against the nuclear threats.

2. Characteristics of Nuclear Explosions: [R1]

Nuclear detonation is the most devastating weapon of mass destruction; a nuclear detonation creates a severe environment including blast, thermal pulse, radiations, electromagnetic pulse, and ionization of the upper atmosphere. Blast effects are marked as ground shock, water shock, creating large amounts of dust and radioactive fallouts. The energy of a nuclear explosion is transferred to the surrounding media in three forms: blast, thermal radiation, and nuclear radiation. For a low altitude atmospheric detonation of a moderate size explosion in one kiloton range, the energy is distributed approximately as follows:

- 50% as blast.
- 35% as thermal radiation (electromagnetic spectrum, infrared, visible, ultraviolet light and soft x-ray) emitted at the time of the explosion.
- 15% as nuclear radiation (5% initial ionizing of neutrons and gamma rays within the first minute after detonation, and 10% as residual nuclear radiation).

2.1. Classifications of Nuclear blasts [R1]

Nuclear explosions are generally classified into:

a) Air bursts.
b) Surface bursts.
c) Subsurface bursts.
d) High altitude burst.

2.2. Delivery of Nuclear weapons

The methods used to deliver a nuclear weapon are an important aspect that depends on both the design and the strategy of the attack. Historically the delivery method used in warfare was the gravity bomb, this method does not place many restrictions on the size of the weapon; but it limits the range of attack. The gravity bomb still considered the primary mean of delivery; the majority of U.S nuclear warheads are represented in free-fall gravity bombs. [R2]

It is best to use a nuclear weapons mounted onto a missile using a ballistic path to deliver a warhead over the horizon, while short range missiles permit a faster and less risk attack. The development of intercontinental ballistic missiles and submarine-launched ballistic missiles has allowed some nations to deliver missiles anywhere on the globe with a high possibility of success, the matter that reduces the chance of any successful missile defense. Today, missiles are the most common system designed for the delivery of nuclear weapons. [R1

3. Nuclear Threat

The main nuclear threat comprises its wide spread ownership, storage and tests in a number of countries as shown in figure. The collapse of the Soviet Union and the unimaginable catastrophe of all out nuclear war have become truly probable. In addition to the probability of using small nuclear weapons in terrorist attacks with the support of countries having a nuclear power, similar to what happened with the biological and chemical weapons. [R3]

There is a vulnerability of using cheap and portable nuclear missile, where shooting a missile is easier with its initial 'boost phase' about 3 minutes immediately after launch, the warhead then separate from the missile, and it can confuse radar. The use of specially designed weapons can avert a destructive ground-level and fallout risks. a sufficiently powerful warhead detonated in space can affect a very wide area. [R5]

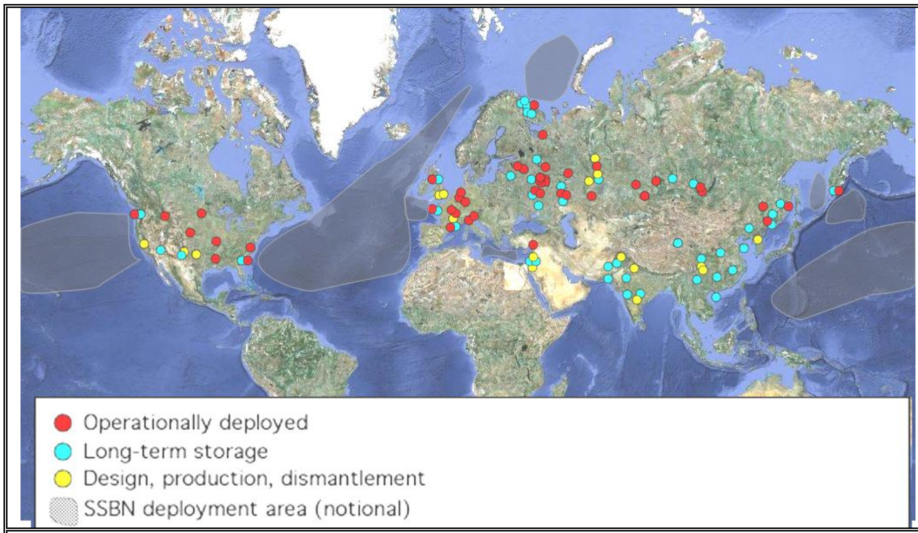

Fig. 1: Locations of nuclear weapons deployment and storage around the world. [R4]

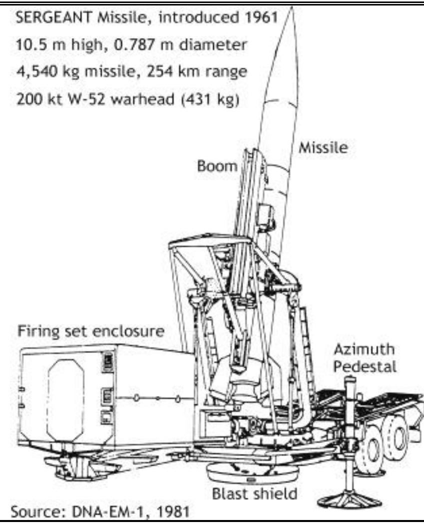

Fig. 2: A sample of light Surface to Surface Missile could be used in a nuclear attack

Fig. 3: B-52 American bomber can deliver many types of warheads

Fig. 4: Russian new contenintal balistic missile

New Russian missiles will easily be able to penetrate any prospective missile shield and will remain unrivalled for the next 15-20 years, the head of Russia's top missile design institute has said [R6]

The disaster of using nuclear bomb can obliterate a whole city similar to what happened in WWII, while the new types destructive effect is even much lighter and stronger. Fig.5. present an estimation to the size of the damage caused by the bombing of Nagasaki. A modern hydrogen bomb would be tens of times more powerful and causes similar levels of damage at 2 to 5 times the distance.[R7]

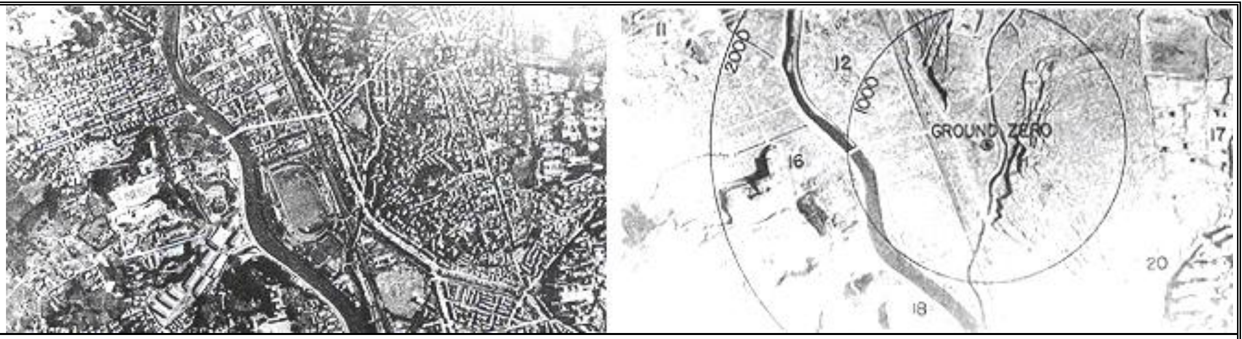

Fig. 5: A photo of Nagasaki before and after the bombing. Each house damaged turned into a kinetic energy or debris. [R7]

4. Nuclear tests on Structures

There have been many tests on nuclear blast effects after the detonation of the two bombs in Hiroshima and Nagasaki in 1945. The available known tests were: Operation UPSHOT-KNOTHOLE at Nevada in 1953, Operation TEAPOT at Nevada in 1955, The Priscilla Nevada test 37 kt in 1957, Operation Blowdown, an Australian-British-American 0.05 kt (50 ton) test Northern Queensland in 1963, and the SAILOR HAT-CHARLIE test 0.5 kt at Kahoolawe Island in Hawaii on 1965. Undoubtedly there are many other unpublished tests until now. [R8, 9, 10]

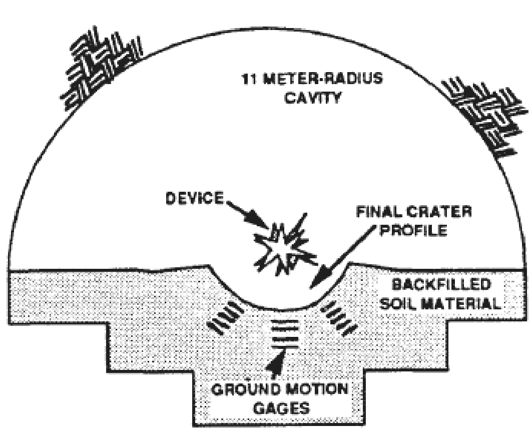

Fig.6: Configuration of an underground Nuclear cavity test. [R 11]

Fig. 7: A railroad bridge from PRISCILLA Nevada test in 1957 had severe distorting to its internal structure.

The purpose of making these tests is to evaluate the nuclear weapons power, and to develop the structures protection design, in addition to the artificial intelligence computer simulating programs, the matter that provides a successful protection design criteria.

In Egypt there still no activated technological programs to withstand the coming threat, and according to USA department of defense: the following table shows that Egypt had limited capabilities to deal with the nuclear power. [R1, 8]

Country	Sec 6.1 Underground Testing	Sec 6.2 Blast and Shock	Sec 6.3 Thermal Radiation	Sec 6.4 TREE and SGEMP	Sec 6.5 Signal Propagation	Sec 6.6 HEMP	Sec 6.7 SREMP	Sec 6.8 Pulsed Power
Australia		♦♦		♦♦		♦♦		
Canada	♦	♦♦	♦	♦♦		♦♦♦		
China	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦	♦♦
Egypt		♦	♦			♦		
France	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦
Germany	♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦	
India	♦♦	♦♦	♦♦	♦♦	♦♦♦	♦	♦	
Iran		♦	♦			♦		
Iraq		♦				♦		
Israel	♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦	♦♦♦	♦♦
Italy	♦	♦♦	♦♦	♦♦	♦♦♦	♦♦	♦♦	
Japan	♦	♦♦	♦♦	♦♦♦	♦♦	♦♦	♦♦	♦♦
Libya		♦	♦			♦		
North Korea		♦	♦			♦		
Pakistan						♦	♦♦	
Russia	♦♦♦	♦♦♦	♦♦♦	♦♦♦		♦♦♦	♦♦♦	♦♦♦
South Africa	♦	♦	♦			♦		
UK	♦♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦
United States	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦

Legend: Sufficient Technologies Capabilities: ♦♦♦♦ exceeds sufficient level ♦♦♦ sufficient level ♦♦ some ♦ limited

Fig. 8 : Nuclear technological capabilities of countries. [R1]

5. Analysis of Nuclear Blast Damage effect on deferent types of structures:

Nuclear warfare has large destructive forces, which needs deep studies to understand its effects. Direct damage to structures exposed to a nuclear air blast can take various forms, such as deflection of steel frames, collapse of roofs, cracks and damage of walls, shattering of glass panels and break of doors and windows. For the purpose of evaluating the various effects of nuclear blast damage on structures, the structures placed in three nuclear detonation regions will be classified into three categories:

a) Surface structures.
b) Underground structures.
c) Field fortification structures.

According to the U.S. Armed Forces Special Weapons Project technical manual, the following tables indicate the damage effect on the deferent types of structures.

Table 1: The effects of nuclear blast damage on deferent types of surface structures [R 12]

Definition of the structure	Description of the damages		
	Sever destruction region 2 Km from detonation	Moderate destruction region 3.2 Km from detonation	Light destruction region 5.6 Km from detonation
1- Multistory RC building, 3 stories, of RC walls, blast resistant designed for 20 PSI pressure, no windows.	- Walls shattered - Frame distortion - Collapse of the 1st floor columns	- Walls cracked - Slight distortion of the structure. - Blown and jamming of doors.	
2- Multistory RC building, 5 stories of concrete walls, small windows.	- Walls shattered - frame distortion - Collapse of the 1st floor columns	- Bad cracks in the exterior walls. - blown and cracks of interior partitions. - Spalling of concrete	- Windows & doors b blown in - Cracks in Interior partitions.
3- Multistory RC building, 3 stories of brick walls	- Collapse of walls resulting in total collapse of structure.	- Bad cracks in the wall facing the blast - Bad cracks or collapse in the interior walls	- Windows & doors b blown in - Cracks in interior partitions.
4- Multistory wall bearing monumental building, 4 stories of brick walls	- Collapse of walls resulting in total collapse of structures supported by it. - Partial damage of the Structure.	- Bad cracks in the wall facing the blast - Bad cracks or collapse in interior walls - Cracks in the far end of the building.	- Windows & doors b blown in - Cracks in interior partitions.
5- Wood frame building, 2 stories	- Shuttering of frames and collapse of the structure.	- Cracks in frames - Bad damage in roofs. - Collapse of interior walls.	- Windows & doors b blown in - Cracks in interior partitions. - Bad damage in the roof.

The safest surface structure in a sever detonation is the RC building with RC walls and no windows. In such case, the need to a natural lighting, ventilation and exposure to the outer environment will be the issue that needs to design windows and doors that offers a good resistance to nuclear detonation effects.

Table 2: The effects of nuclear blast damage on deferent types of underground structures [R 12]

Definition of the structure	Description of the damage		
	Sever destruction region 2 Km from detonation	Moderate destruction region 3.2 Km from detonation	Light destruction region 5.6 Km from detonation
Relatively small, heavy, well designed structure	- Total collapse of the structure.		- Slight cracks. - Danger brittle external connections.
Relatively long, flexible structure using pipelines system.	- Deformation and rupture.	- Slight deformation and rapture.	- Failure of connections

The safest underground structure in a sever detonation is the long flexible structures using pipelines system. In such case the need to overcome the problem of making a successful circulation in an elongated system will be the issue, in addition to overcome the physical and physiological disadvantages of being underground.

Table 3: The effects of nuclear blast damage on deferent types of field fortifications structures [R 12]

Definition of the structure	Description of the damage		
	Sever destruction region 2 Km from detonation	Moderate destruction region 3.2 Km from detonation	Light destruction region 5.6 Km from detonation
Command post and personal timber underground shelter, earth covered, trench entrance	- Break in caps and posts - disarrange of the structure. - Revetment failure.	- Some breaks in caps and posts - Moderate displacement - Some revetment failure.	- Damage to minor components - Slight displacement - Probable revetment failure
Machine gun underground emplacement, framework above, trench entrance, earth cover	- Break in caps and posts - Large displacement - disarrange of the structure. - Revetment failure.		
Un-revetted, fox holes, with light cover	At least 50% failure and filled with earth	At least 10% failure and filled with earth	Less than 10% failure and filled with earth

The safest field fortified structure in a sever detonation is the command post structures due to its importance in managing field operations, the problems are to offer a good camouflaged system, design a good circulation system offering suitable outlets, technical installations and ventilation system to withstand the nuclear detonation effects.

From the other side the following architectural elements of the structures exposed to a nuclear threat will be examined in order to evaluate the effect of nuclear forces on it

1- Facades and exterior walls
2- Roofs and shells.
3- Windows and doors
4- Interior walls and partitions
5- Technical installations (water supply – sewage system – electric high and low current –air conditioning – security and monitoring systems).

The following table shows the forces that could affect the architectural elements:

Table 4: The effects of nuclear forces on the structure architectural elements

Architectural element		Nuclear energy and forces threaten the element			
		Blast power		Thermal power	Electro-magnetic force
		direct	indirect		
Facades and exterior walls		*		*	
Exterior windows and doors		*		*	
Roofs and Shells		*		*	
Interior walls and partitions			*	*	
Technical Installation Systems	Water supply system	*	*	*	
	Sewage system	*	*	*	
	High current electric system		*	*	
	Low current electric system			*	*
	Air conditioning system	*	*	*	
	Security and monitoring systems	*	*	*	*

There is a difference between the nuclear blast effect and the conventional high-explosive bomb, the nuclear blast is a combination of high peak over pressure, high wind dynamic pressure, very high thermal power, and a long duration of compression phase surround and destroy the whole structure resulting in a mass destruction of the structure, while an ordinary explosion usually damages only a part of the structure. [R 8]

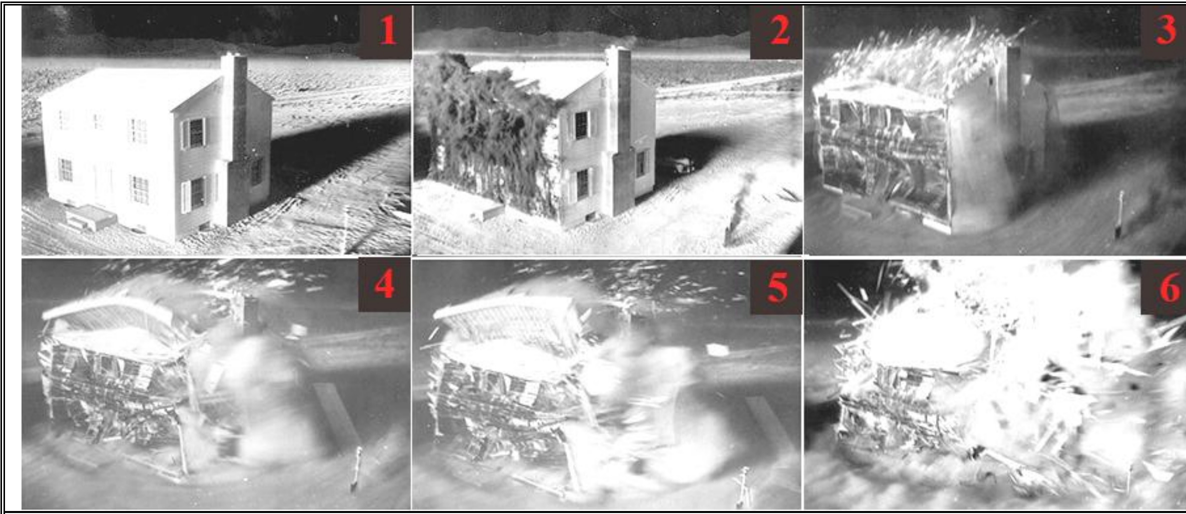

Fig. 9: American wood frame house survived unburned 25 cal/cm2 thermal radiation, but it was blown up by 5 psi (35 kPa) peak overpressure at 3,500 feet from 16 kt ***UPSHOT KNOTHOLE-ANNIE*** . [R8]

6. Conclusions:

1- There is a need to understand the nature of the nuclear threat, to evaluate the threat, start dealing with it to mitigate its hazards.

2- Egypt still has a limited nuclear testing technology capability, which in turn needs to start a nuclear technology programs and systems to enable the country to develop its protective systems.

3- As a result of the previously studied effects of nuclear explosions on various types of structures, the following conclusion could be deduced:

   a) Small masonry and light structures collapsed completely when exposed to the nuclear blast effect.

   b) Steel constructions roofing and siding will be removed and its frames were twisted when exposed to the nuclear blast effect.

   c) The heavy reinforced concrete structures may be remained when exposed to the nuclear blast effect, but it will be threatened by the fires and loss of water due to the breaking of supply pipes, the result could be its collapse due to fires after all.

   d) After the nuclear explosion enormous number of flying debris due to the blast causes a considerable secondary damage to the remaining structures.

   e) The strongest structures are heavily framed steel and reinforced concrete structures especially those designed to resist earthquakes, while the weakest were shed-type light frames structures, wide span, and wall-bearing structures of masonry walls without reinforcement, that it had a weak resistance due to its connections moderate strength. Ideally, a structure which is to suffer little damage from a nuclear blast should have a much ductility as possible, this could be achieved by using materials, construction elements, and designs capable of absorbing energy in elastically without failure.

4- Towards a developed nuclear design technology we need to:

a) We need to allocate a financial investment for nuclear testing programs.
b) Apply a physical simulation tests and computer programs to evaluate the destructive effect of nuclear forces on deferent designs.
c) Preparing a qualified team works to establish a building code for nuclear threats protection.
d) Establish a building code to protect structures against nuclear threat.
e) Allocate a sufficient shielding space in each new structure, as a restriction to have a building permission.
f) Start to establish a nuclear protection education courses in the engineering faculties.

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