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THE USE OF UNDERGROUND GARAGES AS PROTECTIVE STRUCTURES IN CASE OF NUCLEAR EMERGENCIES

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This paper discusses the use of underground garages as protective structures. Three underground garages are taken as case studies; underground garage at El Darrasa, first underground garage under the Tahrir square and second underground garage under the Tahrir square, in order to investigate the use of several parts of their basement floors as protective structures in case of emergencies. A field study has been conducted to the garages. This study aims to identify; the planning, the design and the general features for each one of them, and to determine whether they can be used as protective structures for citizens in emergencies. The basements of the three underground garages were studied and compared. Their protective factors from radiation (PF) and their numeric capacity for sheltering people were calculated.

Keywords: *Underground Garages, Protective Structures, Nuclear Emergencies, Nuclear Shelters, Protective Factors.*

INTRODUCTION

Whenever a nuclear explosion took place near earth's surface or immediately above it, a glowing ball on earth's surface will be formed. Consequently, thousands of tons of soil will be crushed, and then evaporated into the air forming a nuclear cloud that takes the shape of a mushroom. This nuclear cloud contains particles of radiant fallout. They are radiant because of exposure to neutrons resulting from nuclear bomb explosion. These particles will be raised above by a powerful air current coming as a result of the explosion. Moving in a high speed it rises to an enormous height that could be more than 2400 m [1]. These fallout particles consist of minor particles, which will fall so fast above the ground in 24 hours from the explosion; and other microscopic particles which are carried by the wind to hundreds of kilometers away from the site of the explosion. Then, it will fall upon some vast areas of buildings and plantations because of the gravity influence. Radiating dangerous gamma radiations which are capable of penetrating buildings walls and ceilings and exposing people's

lives to danger [2]**.** Fallout consists of radioactive atoms that radiate gamma radiations, which are electromagnetic beams of high energy. Like (X) rays they are capable of spreading and penetrating so fast. The density of the radio activity of the fallout will decrease in fixed rates by the passage of time until they fade away. The areas that are affected by gamma radiations will be considerably wider than those which are affected by storms and initial nuclear radiation [3].

Developed countries are capable of building shelters that suffice most of its citizens from different building materials. These countries also make dual-use of basements as shelters. In which people can hide from the nuclear explosion, so that they can protect themselves from the exposure to gamma radiations emanating from fallout [4]. Individual who do not seek protection inside shelters will die because of their exposure to gamma radiations radiating from fallout. Also people die after exposure to infiltrating gamma radiations from nuclear reactors in nuclear crises, such as that which happened in Chernobyl reactor. Therefore, citizens must be protected against its possible consequences, and from radiating gamma radiations through hiding in nuclear shelters whether being domestic or public shelters [5]. Thus, nuclear shelters are equal in their importance to arming for protecting mankind from the destruction resulting from using the nuclear weapons. Underground garages as opposed to public buildings are special in the fact that most of their spaces are designed for receiving congregations of cars for a period of time. So why not make use of this property by designing them as protective structures in case of national emergencies? Most of the developed countries have used their underground garages as protective structures in emergencies, after providing them with equipment and necessary supplies, to protect their citizens from the bad effects of traditional weapons (pressure and shrapnel) or that of nuclear weapons; especially gamma radiations emanating from fallout. Therefore, the underground garages can also be used as protective structures in emergencies to protect citizens from dangers [6].

1. The Selected Underground Garages

Three underground garages have been selected and a field study has been conducted to their floors to determine the usages of these floors; in addition to the planning, design and general features for each one of them; and to determine whether they can be used as protective structures for citizens in emergencies. These underground garages are as follows:

1.1. Underground Garage at El Darrasa

This garage is located in El Darrasa District, in front of Al-Hussein University Hospital and near Al-Hussein Mosque and Al-Azhar Mosque. The garage serves the people of the regions of Al-Hussein and El Darrasa. El Darrasa garage consists of 4 underground floors and 4 aboveground floors. The aboveground floors are a five stars tourist hotel on the Islamic style, consists of 100 rooms. The underground floors are a garage. The total area of the underground floors is 36 thousand square meters. The garage can accommodate 600 vehicles. The garage contains parking areas, shops, bowling, cinema (400 persons), reception, cafeteria, courts, electricity rooms,

transformers rooms, security rooms, administration rooms, control rooms, toilets, water tanks, staircases, escalators, elevators, stores and pumps rooms, generators rooms, fuel tank room, chillers and workshops [7]. The garage is partially located under the ground surface. It's structure is consists of reinforced concrete. It's walls are consist of high thickness preventing gamma radiations emanating from fallout from penetration into this garage. Thus, it is qualified for dual use as a traditional or nuclear shelter.

Figure 1. Basement floor plan (-1) of Underground Garage at El Darrasa.

Figure 2. Basement floor plan (-2) of Underground Garage at El Darrasa.

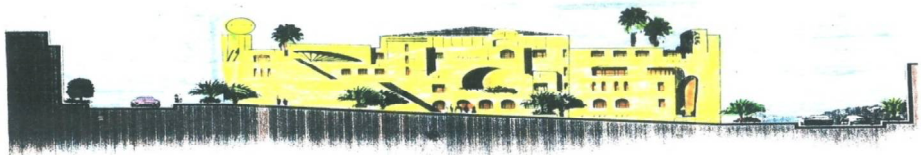

Figure 3. Main Elevation of Underground Garage at El Darrasa.

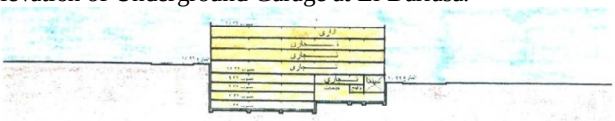

Figure 4. Cross Section of Underground Garage at El Darrasa.

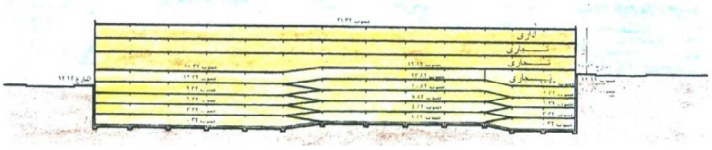

Figure 5. Longitudinal Section of Underground Garage at El Darrasa.

1.2. First Underground Garage under Tahrir Square

This garage is located under Tahrir Square, in front of League of Arab States and near National Museum and Omar Makram Mosque. The garage serves the people of the regions of El-Tahrir and Downtown. This garage consists of 4 underground floors. The total area of the 4 underground floors is 84 thousand square meters. The garage can accommodate 1400 vehicles and 50 buses. The garage contains parking areas, shops, reception, cafeteria, courts, electricity rooms, transformers rooms, security rooms, administration rooms, control rooms, toilets, water tanks, staircases, escalators, elevators, stores and pumps rooms, generators rooms, fuel tank room, chillers and workshops [8]. The garage is totally located under the ground surface. It's structure is consists of reinforced concrete [9]. It's walls are consist of high thickness preventing gamma radiations emanating from fallout from penetration into this garage. Thus, it is qualified for dual use as a traditional or nuclear shelter.

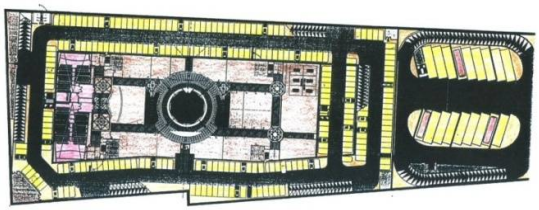

Figure 6. Basement floor plan (-1) of First Underground Garage under Tahrir Square.

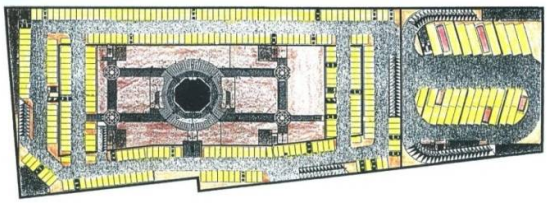

Figure 7. Basement floor plan (-2) of First Underground Garage under Tahrir Square.

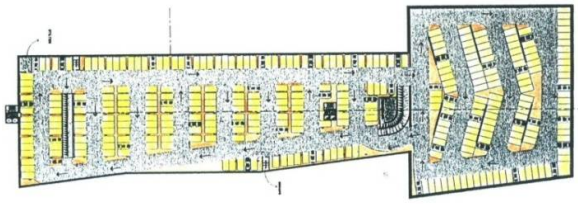

Figure 8. Basement floor plan (-3) and (-4) of First Underground Garage under Tahrir Square.

Figure 9. Cross Section of First Underground Garage under Tahrir Square.

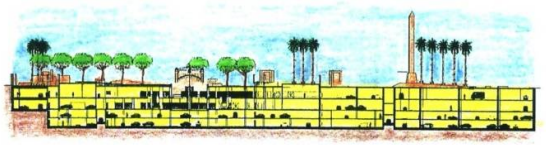

Figure 10. Longitudinal Section of First Underground Garage under Tahrir Square.

1.3. Second Underground Garage under Tahrir Square

This garage is located under Tahrir Square, in front of Omar Makram Mosque and near Tahrir complex and Ministry of Foreign Affairs. The garage serves the people of the regions of El-Tahrir and Downtown. This garage consists of 4 underground floors. The total area of the 4 underground floors is 20 thousand square meters. The garage can accommodate 400 vehicles. The garage contains parking areas, shops, reception, cafeteria, electricity rooms, transformers rooms, security rooms, administration rooms, control rooms, toilets, water tanks, staircases, escalators, elevators, stores and pumps rooms, generators rooms, fuel tank room, chillers and workshops [10]. The garage is totally located under the ground surface. It's structure is consists of reinforced concrete [9]. It's walls are consist of high thickness preventing gamma radiations emanating from fallout from penetration into this garage. Thus, it is qualified for dual use as a traditional or nuclear shelter.

Figure 11. Basement floor plan (-1) of Second Underground Garage under Tahrir Square.

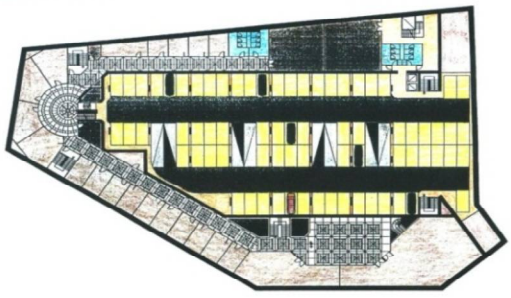

Figure 12. Basement floor plan (-2) of Second Underground Garage under Tahrir Square.

Figure 13. Basement floor plan (-3) and (-4) of Second Underground Garage under Tahrir Square.

Figure 14. Cross Section of Second Underground Garage under Tahrir Square.

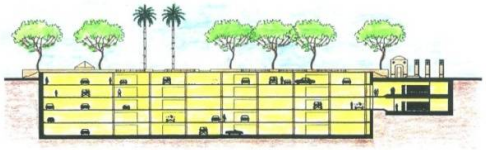

Figure 15. Longitudinal Section of Second Underground Garage under Tahrir Square.

2. Planning, Design and General Features of the Selected Underground Garages

A field study has been conducted to the garages. This study aims at identifying the planning, design and general features for each one of them, and determining whether they can be used as protective structures for citizens in emergencies. The following is the results of this field study.

Table 1. Planning features of the selected underground garages.

No.	Subject	Details	El Darrasa garage	First Underground Garage under Tahrir Square	Second Underground Garage under Tahrir Square	Rate
1	Current use of the garage	Used	√	√	√	100%
		Unused				0%
2	Users of the garage	Limited				0%
		Unlimited	√	√	√	100%
3	Usage of the garage	For Parking and stores	√	√	√	100%
		For parking only				0%

4	**Height of the garage**	High				0%
		Medium	√	√	√	100%
		Low				0%
5	**location of the basement inside the building**	Under the whole building	√	√	√	100%
		Partially under				0%
6	**Ceiling level comparing to ground level**	Ceiling above land surface	√			33%
		Ceiling under land surface		√	√	67%
7	**Basement Entrance**	Inside and outside the building	√	√	√	100%
		Inside the building only				0%
8	**Access to the basement "from inside the building"**	By using stairs				0%
		Using stairs and lift	√	√	√	100%
9	**Access to the garage "for cars"**	Fast and easily	√	√	√	100%
		Hardly and taking a lot of time				0%
10	**Site of the garage in relation to the other buildings**	Surround by buildings from all the 4 sides	√	√	√	100%
		From 3 sides only				0%
		From 2 sides only				0%
		From 1 side only				0%
		Away from the other buildings				0%

11	**Access to the garage for people in the streets**	Direct and easy	√	√	√	100%
		Complicated and difficult				0%
12	**Guiding signs lead to the garage**	There are some	√	√	√	100%
		There are not any				0%
13	**Cleanliness of the garage**	No offensive smells	√	√	√	100%
		Offensive smells				0%
		Leakage				0%
		Rubbles and debris				0%

Table 2. Design features of the selected underground garages.

No.	Subject	Details	El Darrasa garage	First Underground Garage under Tahrir Square	Second Underground Garage under Tahrir Square	Rate
1	**Number of garage stories**	1 story				0%
		More than one	√	√	√	100%
2	**Plan of the garage**	Simple	√	√	√	100%
		Complex				0%
3	**Number of entrances to the garage**	1				0%
		2 one from inside, the other from outside				0%
		More than 2	√	√	√	100%
4	**Number of emergency outlets of the garage**	1				0%
		2 or more than 2	√	√	√	100%
		No one				0%
5	**Basement Door from the direction of the main stair of**	Door made of Aluminum and glass				0%
		Fire gate	√	√	√	100%

	the garage	No doors				0%
6	**Garage Ramp Door**	Aluminum door with glass				0%
		Iron door with glass				0%
		Massive iron door				0%
		Safety iron door	√	√	√	100%
7	**Internal Doors**	Iron plated with lead				0%
		Iron	√	√	√	100%
		Aluminum				0%
		Wooden				0%
		No internal doors				0%
8	**External walls**	Reinforced concrete	√	√	√	100%
		Brick of 12cm				0%
		Brick of 25cm				0%
9	**Finishing**	Walls	Tiles				0%
			Painting	√	√	√	100%
			Ceramics				0%
			Plaster				0%
			Marble				100%
			No				0%
		Ceiling	Painting	√	√	√	100%
			Plaster				0%
			No				0%
		Floors	Tiles				0%
			Ceramics				0%
			Asphalt	√	√	√	100%
			Marble				0%
			No				0%
10	**Ventilation**	Through windows and entrances					0%
		air conditions		√	√	√	100%

		No ventilation					0%
11	**Lightening**	Fixed in the ceiling		√	√	√	100%
		Fixed in walls					0%
		No lightening					0%
12	**Sanitation services of the basement**	Water reservoir	Sufficient	√	√	√	100%
			Insufficient				0%
			No reservoir				0%
		Toilets	Some	√	√	√	100%
			No toilets				0%
		Basins	Some	√	√	√	100%
			No basins				0%
		Sanitation	Exist	√	√	√	100%
			No sanit.				0%
13	**Other Equipment**	Fire extinguisher	Exist	√	√	√	100%
			Not exist				0%
		Fire wheels	Exist	√	√	√	100%
			Not exist				0%
		First Aid Kits	Exist	√	√	√	100%
			Not exist				0%

Table 3. General features of the selected underground garages.

Name of the garage	Garage area (m^2)	Capacity "Number" of hidden people it can take in emergencies
Underground Garage at El Darrasa	36000	18000
First Underground Garage under Tahrir Square	84000	42000

Second Underground Garage under Tahrir Square	20000	10000

3. Spaces need to be assigned inside the selected underground garages used as protective structures [11]:

Each floor will be divided into various spaces, these spaces will be:

1- Entrances:

Entrances of garages have to be wide to facilitate the entering of hidden people. However, there is a need of fixing plated doors resisting radiations and high pressure; fire gates have to be opened form both directions.

2- Emergency Outlets:

Some of the garages entrances may be used as outlets in emergencies to ease the coming out of the hidden people.

3- Spaces for living, sleeping, eating meals:

Garages floors can be covered with plastic mats to be used for sitting, sleeping, eating; these mats can easily be stored when reusing, the garage in peaceful times.

4- A space for storing water and food.
5- A space for preparing food.
6- Spaces for medical services and first aids.
7- Space for officers supervising the process of hiding inside the garage.
8- A space for equipment and the electricity generator.
9- A space for lavatories [in garages that lack hygienic-systems].

Figure 16 shows the spaces of the nuclear shelter. The entrance passage should be provided with a door and stairs leading to the decontamination space where there are a basin and a toilet. This space leads then to the main space of the shelter which may be divided into the living space, the sleeping space, the cooking space, storing space, eating space and equipment space. This main space leads to an escape passage.

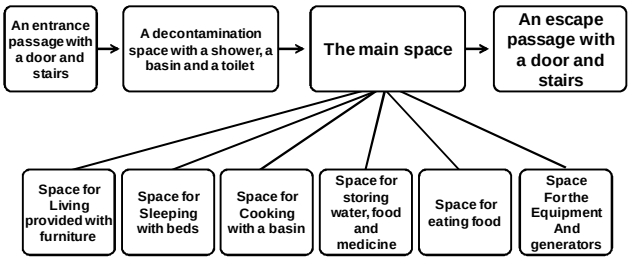

Figure 16. Spaces of the nuclear shelter.

4. Necessary Needs for People Hidden in Underground Garages Used as Protective Structures [12]:

1- Ventilation and Filtration:

The floors of the underground garages are ventilated by air conditioning systems. Therefore, the volume of air is sufficient for the hidden people, also, the temperature is suitable as it ranges from 20^{o} to 28^{o}, and moisture is also appropriate. The concentration of carbon dioxide in air is not exceeding (1%) of air volume; also the air does not include any rate of carbon monoxide, and there is no offensive smells. All these factors make underground garages suitable for hiding. However, there is a need for fixing air filters to clarify the air from the entrance of radiating particles and fallout.

2- Food:

Food need to be provided in sufficient amounts to the hidden people as each one needs from (1500 – 2000) calorie each day.

3- Water:

There are water supplies in all of these underground garages. But for the garages that lack these water supplies, water should be reserved in reservoirs for drinking and other usages. At least (10 liters) for each person per day.

4- Sanitation and Toilets:

All of these underground garages have sanitation systems, however, there should be lavatories and hygienic systems.

5- Lighting:

These underground garages are provided with florescent bulbs giving comfortable lighting range from (100 – 300) lux, however, there should be a system of lightings used in emergencies, especially in vital sites, with separate batteries and special keys.

6- Electricity needs:

The underground garages are provided with electricity. It is preferable fixing a spare electric generator in a safe chamber inside the garage works by diesel that can be stored inside a reservoir close to the electric generator. The underground garage also has electricity key plates, and a safety system against thunderbolts; fire, as it automatically cuts off electricity. There is also fire alarm systems, consists of sensors for heat or smoke, distributed in different places inside garages, responsible for giving signs to the officials to avoid fire. Also, underground garages are well provided with fire-extinguishers fixed in different places. There are also internal telephone lines and external telephone lines for calling the civil defense forces in case of emergencies. It would preferable fixing communication systems for giving instructions to the hidden people; also providing wireless communication systems for calling officials; a system for receiving radio and television transmission and providing safety systems to electric equipment against electromagnetic pulses that could hinder their working, or causing their burning.

7- Medical supplies:

8- Oxygen cylinders:

In first aid room there should be provided oxygen cylinders for being used in treating people who suffer from dyspnea because of the rise of CO_2 rate in air.

9- Safety valves against pressure:

These valves would mitigate the pressure resulting from the explosion inside garages.

10- Color and Aesthetics:

Underground garages should be painted with nice colors, which would have a positive effect on the psychological state of the hidden people.

11- Sound / Noise:

Sound is calm inside underground garages (less than 40 D) which provide a comfortable atmosphere for the hidden people.

5. Protective Factor

The protection afforded by a building against the gamma radiation from fallout is expressed as the protective factor (PF) of the building; that is the factor by which the dose-rate received by a person inside the building is reduced as compared with that received by a person standing in the open on flat ground. Thus, if a building has a PF of 100 it means that the dose-rate inside the building is $1/100^{th}$ of the dose-rate outside [13].Generally speaking, most materials have the ability of absorbing gamma radiation but in different levels of efficiency. This can be determined according to the type of the material; the more the density and solidness of this material the more will be its efficiency in preventing the entrance of these radiations. Consequently, lead and iron are better in their efficiency of absorption of beams than aluminum ... etc. [14]. It would be better if the protective factor of a shelter or of a building used as shelter be of a high rate, especially for the shelter, that are near strategic targets. Therefore, the required degree of protection of a shelter depends on the strategic importance of it; and it would be preferred if the protective factor (PF) of any shelter be not less than 40 [15].

5.1 The PF of a shelter and its location inside the building

The site of shelter inside a building determines its ability of providing safety against gamma radiation from fallout resulting from nuclear explosion; in other words it determines the protective factor degree of a shelter. The protective factor decreases whenever we rise up to the high floors towards the ceiling, because of the influence of the radiations emanating from fallout above the ceiling; and it also decreases whenever we descend to the lower floors to the ground floor because of the influence of the radiation emanating from fallout above the land surrounding the building. However, the value of protective factor increases suddenly in the basement because it is situated under the level of the ground. So that, the basement is the best place in which the inhabitants of the building can hide as it has the highest degree of protective factor than the other places inside the building [16].

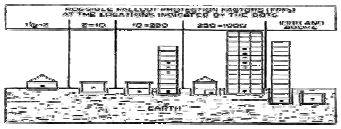

Figure 17. Fallout protection available in various structures [17].

5.2 The Manual Method for Calculation of Protective Factors of Nuclear shelters

Radiation from fallout enters the building from five plane sectors; one on the roof and four on the ground. Each of the five sectors is regarded as providing a separate contribution to the radiation intensity inside the building and each contribution is calculated as a percentage of the total intensity outside. The contributions are then summed to give the total percentage of the total intensity outside. The contributions are then summed to give the total percentage intensity inside and the reciprocal of this fraction is the protective factor. It is easier to use a standard proforma for tabulating data on building construction and the subsequent calculation of protective factors. This method has been used to calculate the protective factors (PF).

A style of proforma [18] **is:**

Roof Contribution:

A_t = Total roof area (m^2)
A_r = Roof area within limits of refuge walls (m^2)
H-x = Distance from roof (m) to a point x (m) above floor
W_o = Weight of overhead material (kg/m^2)
W_w = Weight of interior wall material (kg/m^2)

Wall Contribution:

A = Floor area of building (m^2)
P = Perimeter length of building (m)
W_e = Weight of exterior wall (kg/m^2)
l = Length of exterior wall (m)
W_i = Weight of interior wall(s) (kg/m^2)
f = Fraction of apertures in walls immediately adj. refuge
h = Height above ground (m)
C_h = Height correction factor (Table 8)
d = Distance from wall to wall of shielding building (m)
W_g = Weight of ground floor wall (kg/m^2)
W_c = Weight of basement ceiling (kg/m^2)
B = Depth of basement floor below ground (m)
C_B = Depth of correction factor (Table 9)

Contribution through roof:

Form 1

Data: $\sqrt{A_t}$ ، $\sqrt{A_r}$ ، H-x ، W_o ، W_w ، $W_o + W_w$

Case 1. Interior wall weight less than 100 kg/m^2

(1) $\frac{\sqrt{A_t}}{H-x}$ =

(2) (Fig. 19) using item 1 and W_o R% =

Case 2. Interior wall weight greater than 300 kg/m^2

(1) $\frac{\sqrt{A_r}}{H-x}$ =

(2) (Fig. 19) using item 1 and W_o R% =

Case 3. Interior wall weight between 100 and 300 kg/m^2

(1) $\frac{\sqrt{A_t}}{H-x}$ =

(2) $\frac{\sqrt{A_r}}{H-x}$ =
(3) (Fig. 19) using item 2 and W_o =
(4) (Fig. 19) using item 1 and $W_o + W_w$ =
(5) (Fig. 19) using item 2 and $W_o + W_w$ =
(6) (Item 3) + (Item 4) – (Item 5) R% =

Contribution through wall:
Form 2 **(Areas above ground)**
Data

A ، $\sqrt{A}$ ، P ، W_e ، l ، W_i ، f
h ، C_h ، d ، $\frac{4l}{P}$ ، $W_e + W_i$

Exterior walls of shelter:

(1) (Table 6) $\sqrt{A}$ and W_e =
(2) (Table 6) $\sqrt{A}$ and 0 kg/m^2 =
(3) (Item 1) x (1-f) + (Item 2) x f =
(4) Wall contribution
Item 3 x $\frac{4l}{P}$ x C_h =

Interior walls of shelter:

(1) (Table 6) $\sqrt{A}$ and $W_e + W_i$ =
(2) (Table 6) $\sqrt{A}$ and W_e =
(3) (Item 1) x (1-f) + (Item 2) x f =
(4) Wall contribution
Item 3 x $\frac{4l}{P}$ x C_h =

Shielding factor:
Shielding building

(a) d = 0 - 1.5 m — contribution reduced by 80%
(Item 4) x 0.20 =
(b) d = 1.5 – 10 m — contribution reduced by 50%
(Item 4) x 0.50 =
(c) d = 10 – 25 m — contribution reduced by 25%
(Item 4) x 0.75 =
(d) d > 25 m — contribution reduced by 0%
(Item 4) x 1 =

Contribution through walls:
Form 3 **(Into basements)**
Data

A ، $\sqrt{A}$ ، P ، W_g ، l ، W_c ، B ، C_B

(1) (Table 7) $\sqrt{A}$ and W_g =
(2) (Table 10) and W_c attenuation =
(3) Uncorrected ground contribution
Item 1 x Item 2 =
(4) Corrected wall contribution
Item 3 x $\frac{4l}{P}$ x C_B =

Protective factor:
Roof contribution **R% =**
Wall contributions **G_T % =**

$$\textbf{PF} = \frac{100}{R+G_T}$$

Table 4. A comparison of the protective factors of the three underground garages, for using them as nuclear shelters in case of nuclear emergencies.

Garage's name	Protective factor of basement (-1)	Protective factor of basement (-2)	Protective factor of basement (-3)	Protective factor of basement (-4)
El Darrasa garage	794	1598	3182	6397
First Underground Garage under Tahrir Square	642	1295	2587	5193
Second Underground Garage under Tahrir Square	491	982	1976	3985

Table 5. A comparison of the capacity of the three underground garages, for using them as nuclear shelters in case of nuclear emergencies.

No. of persons accommodated	El Darrasa garage	First Underground Garage under Tahrir Square	Second Underground Garage under Tahrir Square
In basement (-1)	4500	10500	2500
In basement (-2)	4500	10500	2500
In basement (-3)	4500	10500	2500
In basement (-4)	4500	10500	2500
Total no. of people accommodated	18000	42000	10000

RESULTS AND CONCLUSIONS

1. First underground garage under the Tahrir square proved to be larger in area than underground garage at El Darrasa which is larger in area than second underground garage under the Tahrir square. Underground garage at El Darrasa contains areas with the highest PF values of the three garages as its basement floors are more protected by concrete walls and several overhead concrete slabs of the complex. First underground garage under the Tahrir square contains areas with higher PF values than second underground garage under the Tahrir square.
2. The selected underground garages have moderate temperatures and are well lighted and ventilated, also they are not noisy. These underground garages are provided with fire alarm systems, and have a number of fire extinguishers, and internal telephone lines. All these underground garages have water supplies and sanitation systems. The total area of the selected underground garages is 140000 m^2, which

can accommodate 70000 persons, can be used as protective structures for the citizens against the dangerous effects of fallout radiations.

3. The floors of the selected underground garages are well designed and structured as they have wide entrances facilitating the entrance of hidden people into the garages. They also have wide corridors characterized by their high ceilings. People can reach so easily to these underground garages either through stairs, lifts, or ramps in few minutes. These underground garages are well isolated from any source of ground water, so that they can be used as protective structures in case of nuclear emergencies.
4. The underground garages which their spaces are well-designed, situated in the best places inside the city, their ceilings and walls are made of the best building materials (regarding to the density and thickness of these materials), all of these factors help in increasing the level of protective factors of these nuclear shelters. The protection factor of an underground garage which has a reinforced concrete wall (thickness: 25cm) range from 491 (-1 B) and 6397 (-4 B), which indicate that the underground garage wall can be used as a shielding against fallout radiations.
5. Most underground garages are characterized by high protective factors (more than 40), as they are partially or totally located under the ground surface; their building structures are of reinforced concrete; their walls are of high thickness preventing gamma radiations emanating from fallout penetration into these garages. Thus, they are qualified for dual purpose use as traditional or nuclear shelters.
6. The intermediate corridors of the lower floors are of the highest levels of protective factors. Thus they are much suitable for the dual-use as shelters. The more the depth of the shelter ground under land surface, the more the protective factor inside the shelter will be. Lower floors of the underground garages proved to be of the highest level of protective factors than the higher floors.
7. The more the density and thickness of the underground garage's building materials, the more the protective factor inside the garage will be. The reinforced concrete material has a high density, so that it prevents gamma radiations from fallout to infiltrate inside shelters and therefore, it is one of the factors that increase the protective factors inside shelters.
8. The protective factor for any underground garage can also be improved by building a screen from blocks and by blocking its openings by sand bags or any material of high density. The more the number of the building floors above the shelter, the more it's protective factor will be.

RECOMMENDATIONS

1. It is recommended to:
   - Fix doors plated with lead to resist pressure and radiations to the external entrances of underground garages, as well as adjust fire gates to open from both sides, as this will ease the entrance of people who seek hiding.

- Fix filters for clarifying air from the penetrating particles of fallout, and of poisonous gases. In addition to, fix safety valves to ease pressure.
- Design some spaces left for different uses inside the underground garages used as protective structures.
- Store sufficient amounts of food for hidden people, and also sufficient amounts of water inside reservoirs for underground garages that lack water supplies.
- Provide underground garages with lavatories and hygienic systems.
- Provide underground garages with oxygen cylinders and first aids kits.
- Fix a lightening system used in emergencies, and a spare electric generator to be used in pivotal sites.
- Fix a number of external telephone lines, wireless lines to phone the civil defense in emergencies.
- Provide communication systems and a safety system against electromagnetic pulses inside underground garages.
- Place directory signs leading to underground garages entrances.
- Paint underground garages with nice colors that will affect the psychological state of the hidden people.

2. Civil Defense Authority is recommended to conduct a field survey of all vital installations and neighboring buildings to determine the buildings, which can be dual-used as protective structures to protect the workers and the citizens and to calculate the protection factor in each of them and to determine the number of people who can be protected by these buildings.
3. Architects and structural engineers are recommended to design underground garages with the concept of being protective structures in case of nuclear emergencies.

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استخدام الجراجات تحت سطح الأرض كمنشآت وقائية في حالات الطوارئ النووية

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يناقش هذا البحث فكرة استخدام الجراجات تحت سطح الأرض كمنشآت وقائية. ولقد تم دراسة ثلاثة جراجات كحالات دراسية و هذه الجراجات هي جراج تحت سطح الأرض بالدراسة والجراج الأول تحت سطح الأرض بميدان التحرير والجراج الثاني تحت سطح الأرض بميدان التحرير من أجل التحقق بشأن إستخدام أجزاء متعدده في أدوار بدروماتهم كمنشآت وقائية في حالات الطوارئ. ولقد تم إجراء دراسة ميدانية علي هذه الجراجات. وتهدف هذه الدراسة الميدانية الي التعرف علي الصفات التصميمية و التخطيطية والعامة لكل واحد من هذه الجراجات وتهدف أيضا الي تحديد هل يمكن استخدامها كمنشآت وقائية لحماية المواطنين في حالات الطوارئ. وتم دراسة ومقارنة معاملات الحماية لبدرومات الثلاث جراجات تحت سطح الأرض من حيث معاملات الحماية من الإشعاع بهم و تم حساب سعتهم الرقمية لإختباء الأفراد بهم.