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A Proposal Matrix to Apply the Life Safety Code to Readjust Existing Assembly Occupancy closed Buildings

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ABSTRACT

Although Architects focus on applying various requirements in designing different types of buildings & projects to achieve human, functional, economics…etc. needs, it is obvious that human safety needs concerning fire protection codes are mostly neglected, which, over time, threatens the safety of buildings. Therefore, many buildings do not fulfill life safety codes, either due to poor implementation or because of legislation causing an immediate danger to society, which requires checking all existing buildings, especially the ones implemented before issuing & applying the life safety code in Egypt. Hence, this paper aims to set a reference matrix to redesign existing buildings, focusing on "Assembly Occupancy Buildings", being one of the most buildings that deal with a diverse number of users and for their common existence in many places. Furthermore, the paper aims to apply the matrix on a selected building and redesigning it according to the life safety code requirements. The paper also presents two buildings in the Faculty of Engineering at Fayoum university and another building at the Administrative Capital University. It also applies the matrix on the Multi-purpose hall of one of the mosques in New Cairo (5th. Settlement). The paper concludes a matrix that includes a set of design decisions to adjust or redesign existing buildings to meet the life safety code requirements.
Keywords: Life safety code - assembly occupancy buildings - readjust designs – existing buildings.

1. INTRODUCTION

Building design relies on many factors, primary amongst which are the Life Safety Code requirements which are applied in varying countries. Notably, although each country has its own set of requirements, they all come close to each other in some requirements, mostly derived from the American code NFPA, whose application is necessary in protecting buildings in case of emergency and disasters.

In Egypt, there happened catastrophic fires in some buildings which did not apply the life safety code requirements. A primary example is the 1997 Horyia Mall building fire [10], which coincided with the issuance of the Egyptian Code, an essential requirement of building design.

According to the life safety code, in case of damage and harm due to the violation of the code requirements, the designer, the contractor, the construction supervisor, and the owner are criminally liable.

Therefore, it is important to identify the code requirements so that they can be integrated in the initial design stages, starting with the architectural concept stage, in which the building is basically structured given the difficulty of meeting the requirements after construction. Despite such difficulty, however, this paper presents a matrix for readjusting the design of existing buildings because it is important to check such buildings to provide protection and safety for human lives.

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Considering the foregoing overview, a set of requirements are set to prepare a matrix to be used to study and analyze a group of buildings in the next part.

1.1. Problem

The ignorance of applying life safety code at the beginning stages of design, which leads to its neglection during building construction. Therefore, it is necessary to find a methodology for applying the code requirements to readjust the design of the existing buildings, especially in Assembly Occupancy Buildings.

1.2. Objectives

A main objective is to develop a reference matrix that contributes to readjust & redesign existing buildings that did not take into account the requirements of the life safety code. Other secondary objectives could be mentioned as follow:

- Analyzing some buildings and determining their response to the code requirements.
- Applying the existing building readjust design matrix on a selected building.

1.3. Methodology

The paper begins with an analytical investigation of a set of designed and existing projects to study the extent of the code implementation. The paper put a matrix to readjust the design of the buildings followed by the applied part in which the matrix of the building readjusting design is applied on an existing building.

1.4. Research Structure

The study is composed of three main parts:

The first part: an analytical study to apply life safety requirements on buildings.

The second part: the matrix of readjusting the design of the existing buildings to apply the life safety code through requirements to be checked in existing buildings.

Part Three: Application of the study approach to readjust an existing selected building.

2. ANALYTICAL STUDY OF APPLYING LIFE SAFETY REQUIREMENTS ON BUILDINGS:

Life safety code is one of the priorities for checking the design of buildings. However, many buildings in Egypt have been constructed without taking this code into account, which exposes many buildings, including some established by educational institutions, to hazards in case of disasters. In the ensuing section, therefore, the paper is to investigate two existing buildings in Fayoum university in Egypt, and a faculty building in the design phase in one university in the Administrative Capital for some reasons as follow:

- The building classified under group (A -2) of assembly occupancy in closed buildings.
- The buildings classified under faculty types.
- The total occupant load exceeds 1000 persons.
- The total height varies from 3 floors to 6 floors.
- The buildings constructed after applying the code in 1998.

2.1. Building of the Architectural Engineering Department at the faculty of Engineering-Fayoum University:

The building consists of a ground floor and three floors, each having a surface area of 2850 m^2. The building includes a group of lecture halls, a library, drawing halls, classrooms, a conference hall and spaces for the teaching staff and heads of departments and laboratories (fig1).

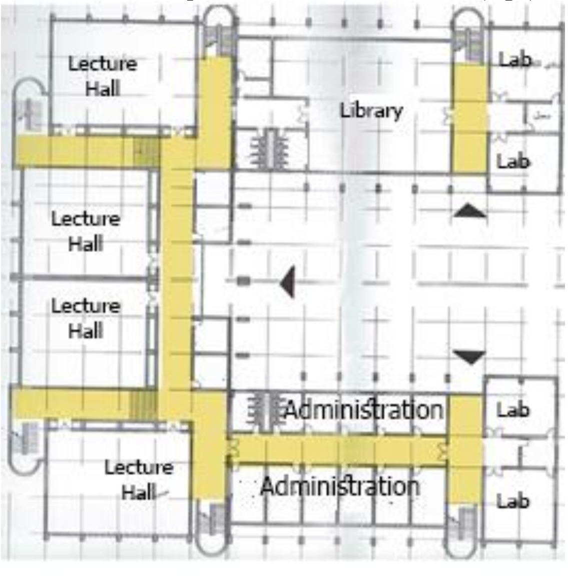

Figure 1: a ground floor plan of the Architecture Department building at the faculty of Engineering, which includes the library, some lecture halls and administration spaces. [4]

2.1.1. Building Classification according to Occupancy Type:

The building classified under the assembly occupancy group (A-2).

The division of the building groups changes from one code to another according to occupancy. In the International Building Code (IBC), educational buildings have a separate section. [9]

2.1.2. Determining the total occupant load:

The total occupant load of the building at maximum use is 3110 students. According to the Egyptian Code, this capacity shall be divided as follows: (860 person on the third floor, 1300 person on the second floor, 150 people on the first floor, 1100 person on the ground floor).

2.1.3. Determining the maximum limits of the travel distance and the dead end.

The travel distances in educational buildings shall have 35 meters length at the level of the exits [1], but the stairs in the building are not secured against fire and smoke as stipulated by the code requirements. Therefore, the travel distances shall be measured from any point up to exist discharge of the ground floor. Consequently, the required travel distances are not fulfilled because they are more than 60 Meters in some parts (fig2). [4]

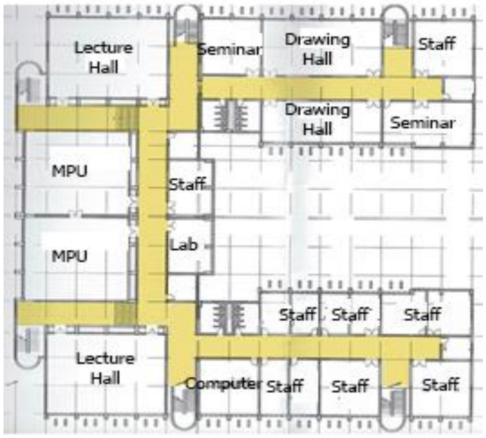

Figure 2: travel distances exceeding 35 meters because the stairs are not secured, and thus the distance is calculated up to the exit on the ground floor. [4]

As for the dead ends, the library area is located in one part of the building, hence completely closing the escape routes of the rear lecture halls area, and still more hazardous, is the fact that it closes the escape route and staircases of the upper halls and lecture halls, which poses grave dangers due to exceeding the dead ends and travel distances (fig3). This requires opening an exit in the building walls before the library area walls whether at the bathrooms, or the librarian location, provided that the building back area is secured.

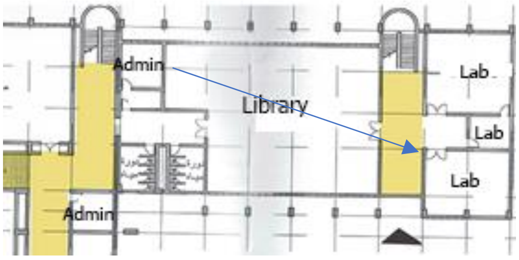

Figure 3: The presence of a dead end behind the library, which was formed due to the closure of the escape exit by the library. [4]

The dead end and travel distances are determined by whether the building is equipped with automatic sprinklers or not. Travel distances increase with the presence of automatic sprinklers. Hence, in assembly occupancy buildings, the travel distance is 35 meters, and if the building is equipped with automatic sprinklers, it is 50 meters while dead ends distance is 6 meters. [1] In accordance with requirements of automatic sprinkler systems design, the educational buildings are classified as low hazard occupancy [3]

Notably, however, the stringent requirements are the ones mostly applied. For example, the Egyptian General Authority for Educational Buildings stipulates that the travel distance from the door of any educational space to the nearest staircase must be 18 meters, a requirement which is strictly applied. [7]

2.1.4. Determining the general requirements for the exit discharge.

Some exit discharges were closed and this requires opening all the ground floor doors and exits located at the ends of all stairs because occupancy load requires six stairs and four exits (fig4).

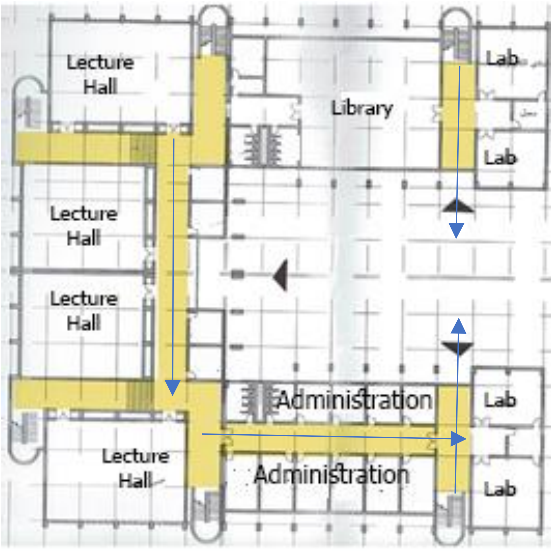

Figure 4: The use of two exits only on the ground floor and the closure of the middle exit in a way that does not meet the requirements of the exit discharge. [4]

2.1.5. Determining the minimum number of exits.

There are some spaces that require a second exit, so that there become two doors for some spaces on the ground floor such as the lecture halls and the library and spaces on the first floor such as the drawing halls, and still for spaces on the second floor such as the conference and lecture halls. [4]

A building can have one exit provided that it meets the following requirements:

- The building does not belong to Occupancy Group (A), or Occupancy Group (F-1).
- The floor height of the highest floor is not more 16 meters above ground level for the occupancy groups.
- The total occupant load of any floor shall not exceed 60 persons, and the area of any floor shall not exceed 600 square meters. [1]

However, some codes require two entrances if the number exceeds 50 persons in case of classrooms and meeting rooms, and if it exceeds 30 persons in cases of, manufacturing spaces, offices and stores. [8]

There shall be fire detection and alarm systems for assembly occupancy buildings, with a height more than 22 meters on the highest floor level. [1] Such systems can be traditional addressable ones which determine the location of the fire or analytical comparative systems that detect fire by exchanging signals between the control panel and the detectors. [2]

2.1.6. Exits Distribution and Spacing

Exits comply with the required spacing and distribution.

2.1.7. Calculating the exits width.

There must be six stairs with 2.00 meters width, a requirement which is not fulfilled. This can be resolved by setting compulsory rules to limit the number of people using the area. For instance, the conference hall shall not be used while using the lecture halls.

The widths of the corridors on the second floor comply with the 6 meters requirement. However, zone dividing doors along with exit signs must be placed to divide the student exits, so that lecture halls exits are distributed on the stairs, separating the movement of the halls and their stairs because in the existing situation the width of the corridor must be 6 Meters in the whole building, a requirement which is not fulfilled. [4]

The widths of the stairs are set according to the International Building Code (IBC) which specify 7.6ml per person from the total occupant load of the highest floor in the building. The widths of the remaining escape routes such as corridors shall be 5.1 ml for each person from the total occupant load. [9]

2.1.8. Calculating doors widths.

There must be four exits (doors) with a total width of 15.5 meters[1], a requirement which is not fulfilled in the existing building.

In light of the above, a review report was made and submitted to the competent authorities to redesign the possible modification and prevention of code violation.

2.2. Workshops building at the faculty of Engineering-Fayoum University:

The building consists of a ground floor and two upper floors with a surface area of 1400 m^2 for each floor (fig5,6). The building includes a group of carpentry and painting workshops, a printing press, a concrete examination center, in addition to laboratories, examination and education halls.

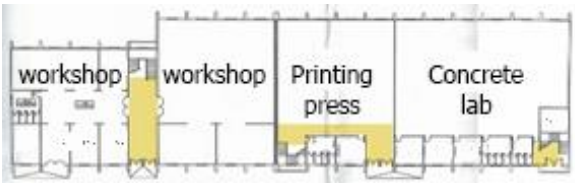

Figure 5: The ground floor plan of the workshop building, including the concrete examination center, the printing press, carpentry and paint workshops. [4]

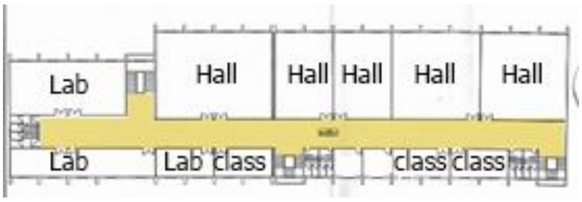

Figure 6: The second-floor plan that includes examination halls and laboratories. [4]

2.2.1. Building Classification According to Occupancy Type

The building classified under the assembly occupancy group (A-2) and industrial occupancy (F-1). With the building having painting and carpentry workshops, it violates code requirements which prohibit simultaneous industrial and educational occupancies in the same building.

2.2.2. Determining the total occupant load:

The total occupant load of the building at maximum use is 1800. Complying with the Egyptian Code requirements, this load is divided as follows: (350 people on the ground floor, 100 people on the first floor, 1350 people on the second floor).

2.2.3. Determining the maximum limits of the travel distance and the dead ends

The travel distances are 35 meters at the level of the exits, but the stairs are not secured against fire and smoke as the code necessitates. Therefore, the travel distances are measured from any point up to the exit discharge on the ground floor. Therefore, and due to the obstructing staircases as well, the travel distances do not conform to the code (fig7,8).

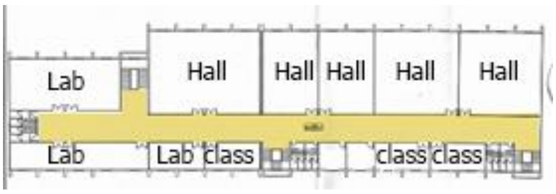

Figure 7: The violation of the required travel distances because the stairs are not secured, hence, travel distances are measured from any point up to the exit on the ground floor.also It shows another violation of the code clear in opening the middle staircase in the printing press space. [4]

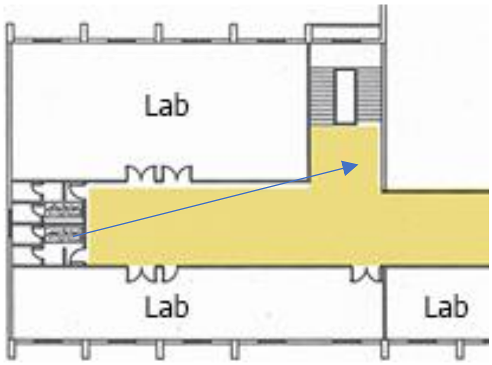

Figure 8: One of the dead ends that exceeds a distance of 6 meters. [4]

As for the dead ends, the allowed distance is 6 meters for the educational buildings and it is not fulfilled in the physics laboratory area on the second floor, which is 12 meters as well as the administration area on the first floor, and the workshops on the ground floor and the printing press (fig 9,10).

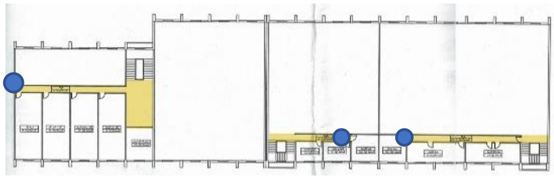

Figure 9: The distances of the dead ends on the first floor, which exceed 12 meters. [4]

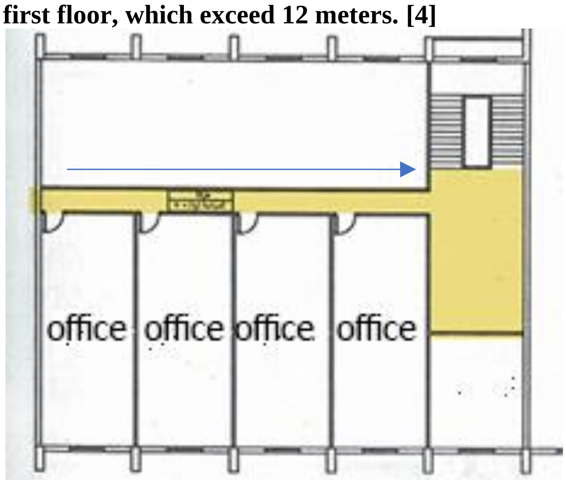

Figure 10: The dead end on the first floor in the administration area. [4]

2.2.4. Determining the general requirements for the exit discharge.

All the doors and exits located at the end of the staircases on the ground floor must be open because the occupant load requires four staircases and four exits, a code requirement which is not met [4]

The areas, especially the workshops and halls, must be separated, while checking exit discharge for each zone, because the middle staircase opens inside the printing press space and from there directly to the outside of the building, which comes in violation of the code (fig11,12).

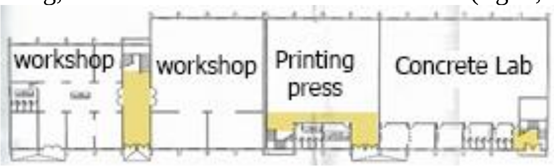

Figure 11: The exit discharge on the ground floor.

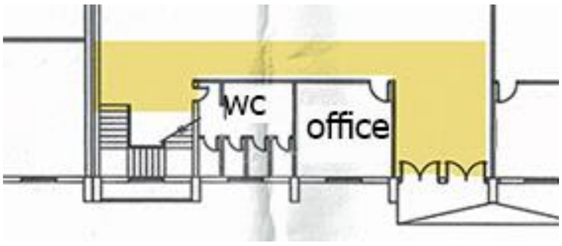

Figure 12: The middle staircases that are connected to and flow into the space of the printing press, in violation of the code requirements for the escape exits and the exit discharge. [4]

2.2.5. Determining the minimum number of exits.

There must be a second exit with two doors in some spaces on the ground floor such as the concrete examination center, the printing press, workshops, and also on the second floor for all halls and laboratories.

2.2.6. Distributing and spacing of exits.

Exits must be separated, because the middle staircases lead to the printing press, in violation of the code requirements. This requires opening the staircases directly to the outside of the building, so that they do not interfere with printing press area.

2.2.7. Calculating the exits width.

According to the code, the stairs width shall be 1.80 meters and it shall have four stairs, a requirement which is not met.

Likewise, corridors on the second floor do not meet the code requirement of 6.50 meters. Zone separating doors and exit signs must be placed to separate the student exits so that hall exits are distributed on the staircases, and separated from the workshop's movement.

2.2.8. Calculating doors widths.

According to the code, there shall be four doors with a total width of 7.5 meters, a requirement which is not met in the existing situation.

In light of the above, a building review report was made and submitted to the competent authorities to redesign the possible modification and prevention of code violation.

2.3. Faculty of engineering building at the Administrative Capital University:

The design was set so that the building consists of a ground floor and three typical floors with each floor having an area of 3850 m^2(fig13). The building is divided into two wings with another three floors and a surface of 1900 m^2 and 1400 m^2 respectively for each floor. The building includes lecture halls, educational classrooms, laboratories, and spaces for the teaching staff and a library (fig14).

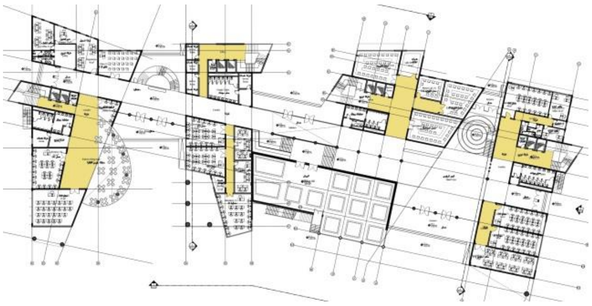

Figure 13: The ground floor plan of the Faculty of Engineering which includes workshop, classrooms, administrative spaces and cafeteria. [5]

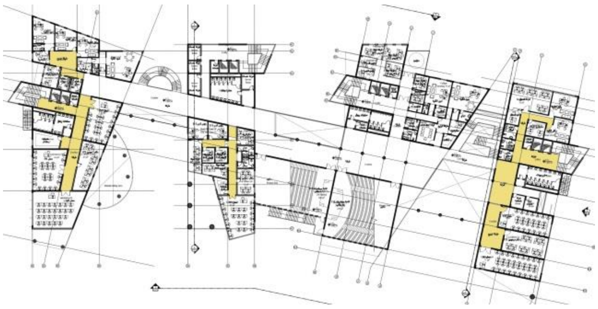

Figure 14: The first floor plan of the faculty of Engineering that includes educational lecture halls, classrooms, laboratories and teaching staff spaces. [5]

2.3.1. Building Classification According to Occupancy Type

The building classified under group (A -2) of assembly occupancy in closed buildings.

2.3.2. Determining the total occupant load:

The occupant load is 700 on the ground and first floors respectively, and 1000 persons on the second and third floors. Occupant load decreases from the fourth to sixth floors to divide the building into two separate wings. The occupant load on the fourth floor is 850 persons.

2.3.3. Determining the maximum limits for the travel distances and the dead ends.

The travel distance of the laboratory on the upper floor is 66 meters, exceeding the maximum allowed limits which is 35 meters. There are some areas where the travel distances are more than 40 meters as well. In some spaces such as those of laboratories and administration areas, dead ends are 20 meters violating the maximum limit according to code requirement, which is 6 meters (fig 15). [5]

Figure 15: The distances of the dead ends, which is 20 meters in some areas. [5]

2.3.4. Determine the general requirements for the exit discharge.

The distances of the exit discharge are about 20 meters mounting to 29 meters in some places, hence violating the maximum limit provided by the code, that is, 15 meters, a case which necessitates equipping the building with automatic water sprinklers. In addition, most of the stairs open inside the building and not directly to outside the building, in violation of the code requirement of opening half of the building's staircases directly to outside the building (fig16). [5]

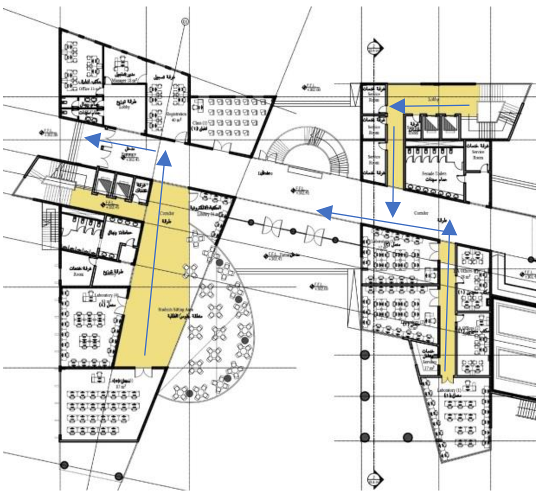

Figure 16: the exit discharge, which is 29 meters on the ground floor. [5]

2.3.5. Determining the minimum number of exits.

According to the occupancy type, the occupant load on the fourth floor of the first faculty is about 700 students and 650 students for the second faculty. Therefore, three staircases serving as fire stairways are required in each wing. What is available are two stairs apart from honorary stairs, which cannot be solely reliable(fig17).

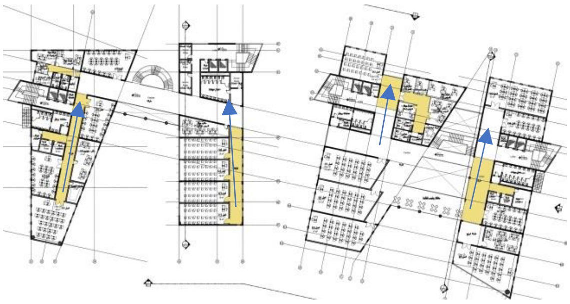

Figure 17: The fifth-floor plan, which shows the division of the building into two separate wings showing the need for stairs that meet the requirements of the code in terms of number, distribution and security, as it requires 3 secured staircases in each wing. [5]

2.3.6. Distribution and spacing of exits.

Except for the dead ends distances, which do not meet the Egyptian code requirements, the exits are spaced out and distributed on the edges of the building.

2.3.7. Calculating the exits width.

In the existing situation, the width of some corridors is within 180 cm, in violation of the requirements of occupant load. For example, the total occupant load of the first floor is about 700 people, and hence, according to the Egyptian code, corridor widths shall not be less than 5.5 meters in case the building does not include divided areas. On the other hand, the total occupant load of the second floor is about 1000 people, and hence, according to the Egyptian code, corridor widths shall not be less than 9 meters in case the building is not divided into zones.
The widths of the stairs, apart from the two honorary stairs which are excluded from the safety life Code provisions, should increase to at least 2.30 meters, [5]

2.3.8. Calculating door widths.

In the existing situation, the door widths fulfill the code requirements.

In light of the above analysis, and after checking the Egyptian life safety code requirements, the design was completely modified (fig18) because the design does not comply with the code requirements as follow:

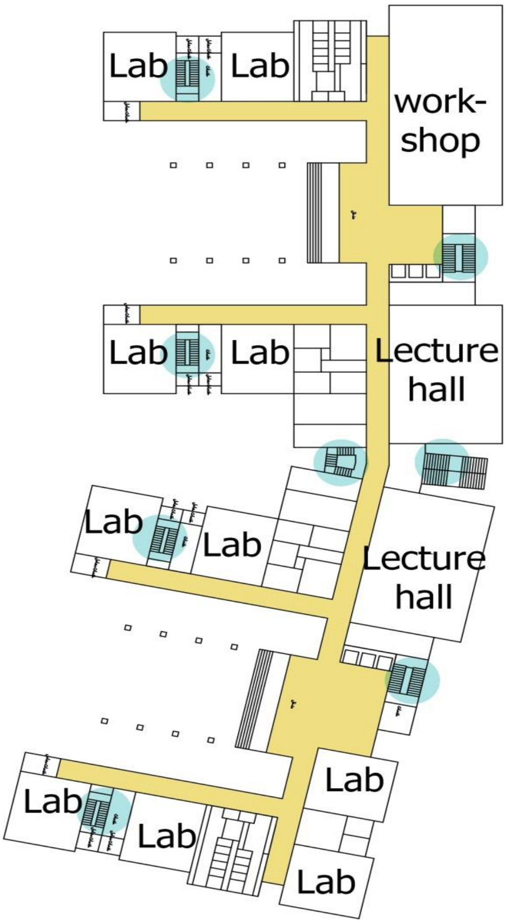

Figure 18: The updated design of the Faculty of engineering building at the Administrative Capital University. [5]

Through the cases studied above and the thorough identification of Life Safety Code violations, a matrix has been set to modify the design of existing buildings so that they can meet the code requirements. Such matrix shall be presented in the next section.

3. The Matrix of Readjusting the existing building design to fulfill life safety code:

A matrix for readjusting the design of existing buildings has been developed to fulfill the requirements of the Egyptian life Safety Code and to ensure that the building sticks to the specified classification according to the occupancy type. The matrix also gives particular attention to the requirements of the total occupant load, the travel distances, the dead ends and the exit discharge in addition to the number of exits and the spacing between them in order to comply with the required exit and door widths.
These requirements were set for existing buildings that were constructed without taking into account the Life safety Code. This is deemed more difficult given that the building has to be modified in order to fulfill the code requirements (table1). The requirements are divided into eight parts as follows:

Table 1: Requirements to be applied in the case of existing buildings.[2]

2-1-Classifying buildings according to the occupant type.		
1	Check the building classification according to occupancy.	Carefully check buildings category (A-2) assembly occupancy and category (F-1) industrial and storage occupancy.
		Check spaces with large numbers of occupants (theater / lecture halls/ seminar halls).
2	Check the multi occupancies.	In case there are two occupancies prohibited to exist simultaneously together, such as Category (A-2) and Category (F-1), one of them shall be moved to another building or the building shall be divided into two separate parts, each with their separate exits.
2-2-Determining the total occupant load:		
1	Check the total occupant load calculations	Focus on calculating occupancy of spaces if they are in floors above ground or underground, especially in the case of cinemas / theater / lecture halls.
		It is possible to move some walls to reduce the area of spaces to less than 600 or 1000 persons so that the number of exits required is reduced.
		Divide the spaces that do not meet escape requirements
		Transfer spaces with a heavy occupant load to the ground floor, so that there is less need to add new staircases.
2	Check fire detector systems.	Add firefighting systems and automatic sprinklers in spaces with more than 300 persons.
2-3-Determine the maximum limits for the travel distances and the dead ends.		
1	Check the travel distances.	take out parts of spaces to add floor corridors in order to use all stairs and reduce travel distances.
2	Check the dead ends	Move some walls and doors to reduce dead end distance.
		joining a group of spaces to eliminate dead ends.
2-4-Determining the general requirements for Exit discharge.		
1	Check the exit discharge	Change the location of the exit doors from one wall to another to reduce distances of the exit discharge.

[2] Source: the researcher.

		Add automatic sprinklers to resolve the exit discharge distances exceeding 15 meters.
2-5-Determining the minimum number of exits.		
1	Check the number of exits.	Increase the doors to ensure that there are at least two exits in the spaces.
		Increase stairs, possibly external concrete ones, to overcome the low number of staircases in case the code requirements are not applied.
2-6-Distributing and spacing of exits		
1	Check the exit distributing.	Increase doors on opposite sides
		Add an external staircase fulfills the required appropriate distribution.
		Divide the space so that it fulfills the required exit distribution.
2-7-Calculating the exits width.		
1	Check the exits width (stairs / corridors).	Check corridor widths to fulfil the code requirement with the possibility of moving walls to increase such width, taking into account the structural elements.
		Reduce the occupant load in spaces by changing their use, and reducing the area of some spaces, especially those with a specific occupant load within the range of 1 m 2.
2	Check the stairs widths calculation.	calculate the widths of stairs while transferring spaces with a high occupant load to the ground floor, which reduces the need to add stairs or increase the widths of stairs.
2-8-Calculating doors widths.		
1	Check door widths.	It is possible to enlarge existing door openings.
		Open new doors to fulfill the total required widths.

After setting these requirements, it was necessary to test their applicability and realistic benefit. Such application is the subject of the next section:

4. Applying the study matrix to readjust the design of the celebration halls in Aasia Mosque in the Fifth Settlement:

The applied study is based on analysis the existing situation then applying a matrix of requirements to readjust the design of the existing buildings as follows:

4.1. Study the existing situation:

The mosque consists of two floors with an area of 1500 square meters for each floor. It includes a prayer hall for men and another for women, in addition to a wedding hall, a medical clinic area, an educational classrooms area and facilities (fig19,20).

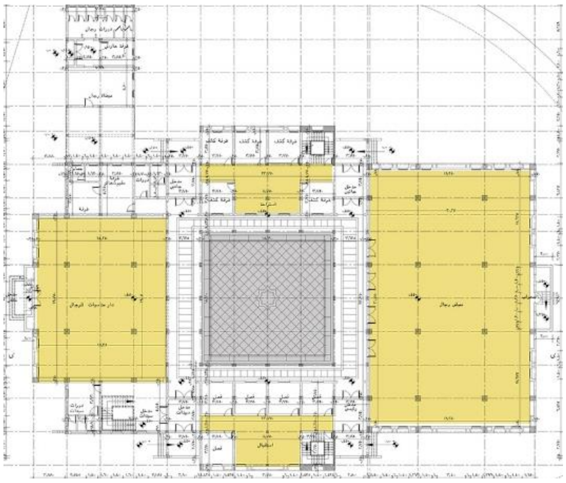

Figure 19: The ground floor plan of the mosque, which includes the men's prayer hall, the men's celebration hall, the classrooms area, and the clinics area. [researcher]

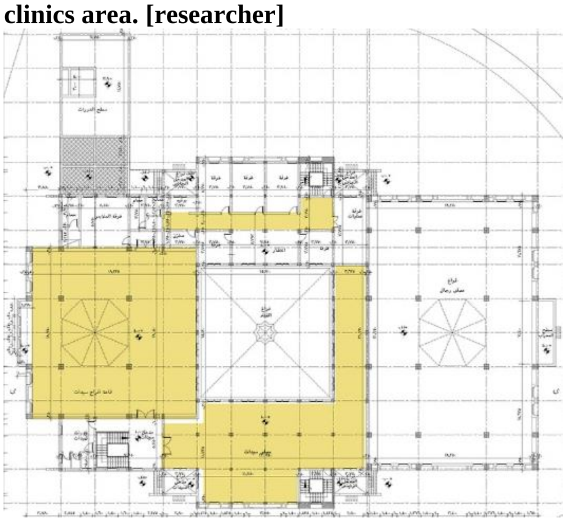

Figure 20: The first-floor plan, which includes the wedding hall, women's prayer hall, and the medical clinics area. [researcher]

4.1.1. Classifying buildings according to the occupancy type.

The building classified under category (A - 2) of assembly occupancy- closed buildings.

4.1.2. Determining the total occupant load:

The occupant load on the ground floor, apart from the inner courtyard, is about 1050 persons, while the occupant load on the first floor is 700 persons.

4.1.3. Determine the maximum limits for the travel distances and the dead ends.

The travel distances comply with the code requirements which don't exceed 35 meters, on the ground floor, but violates the code on the first floor. The dead end of the clinic area is 18 meters on the ground floor, while that of women's prayer area is 23 meters (fig21).

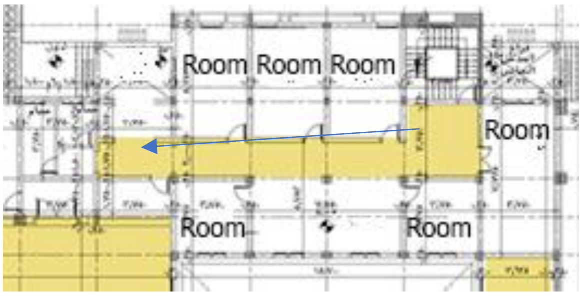

Figure 21: The dead end in the clinics area, which is 18 meters, in violation of the code requirements.

4.1.4. Determining the general requirements for the exit discharge.

The exit discharge meets the requirements given that it is not more than 15 meters, and all stairs open to the exits and thereof to the outside of the building.

4.1.5. Determining the minimum number of exits.

The number of exits does not meet the code requirements, as the wedding hall on the first floor has only one exit although the occupant load is 400 persons, which requires two exits (fig22).

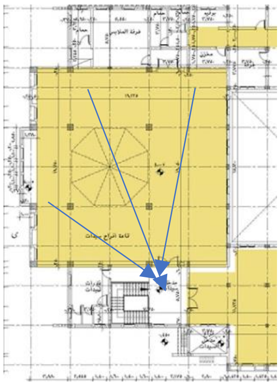

Figure 22: The availability of only one exit for the wedding hall, in violation of the requirements of the code. [researcher]

In addition, the occupant load of the first floor is 700 people, which requires three stairs which is not fulfilled because the stairs of clinics area as well as those in the women's prayer room are separated. This means that the three staircases cannot be used as exits.

4.1.6. Distributing and spacing of exits.

on the ground floor, exits are distributed and spaced out. However, on the first-floor zones are completely separated, with the ultimate result of dividing the floor into three sections: the wedding hall, the women's prayer room and the clinics rooms, which necessitates making more exits and stairs to comply with the code (fig23).

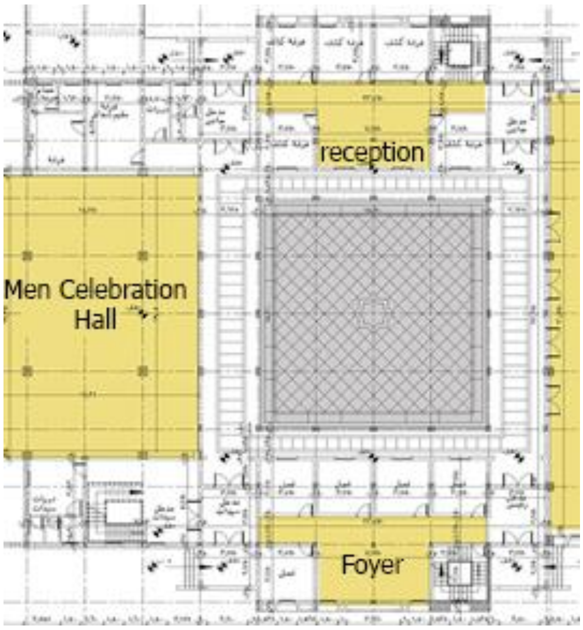

Figure 23: The separation of the 3 zones in the first floor which are wedding hall, women's prayer hall and the clinics zone. [researcher]

4.1.7. Calculating the exits widths.

The total width of the stairs in the existing situation is 3.25 meters, while the occupant load of 700 people for the first floor requires a total staircase width of 6.6 meters [3]according to the Egyptian code, that is, the stair widths should increase to 3.35 meters, which, in turn, requires increasing the number of stairs in building.

The corridors comply with the required widths given that, apart from the corridors of the sub-areas, they are 4 meters in places of gatherings and main circulation.

4.1.8. Calculating doors widths.

The required door widths of the wedding hall on the first floor are not met, as the hall has a total occupancy of 400 persons and the width of the door is 1.60 meter, which does not meet code requirement regarding the required number and spacing.

4.2. Applying the architectural readjust design matrix:

The formerly listed matrix for readjusting the design of existing building was applied as follows:

4.2.1. Building classification according to the occupant type.

Spaces with a high load of occupants (wedding hall /women's prayer hall / Event hall for men) were checked and, as a result, additional exits and a staircase serving the first floor were added.

4.2.2. Determining the total occupant load:

The area of the wedding hall has been reduced from 400 square meters to 300 square meters to reduce its occupant load to be 300 people. In this way, it was possible to add a corridor to connect movement zones on the first floor while facilitating access to the floor exits via all first-floor

[3] exit unit capacity is 60 people, unit width is 55 cm, hence requiring 12 units.

stairs. As a result, too, the need to use automatic sprinklers in the building is reduced[4].

4.2.3. Determining the maximum limits of the travel distances and the dead ends.

The travel distances are checked to ensure that they do not exceed 35 meters in accordance with the code requirements.

A corridor was added on the first floor to reduce travel distances while facilitating access to all stairs serving as exits (fig24). Doors were also added to the wedding hall on the corridor to reduce travel distances.

The design has been modified so that the length of any dead end does not exceed 6 meters in accordance with the code requirements.

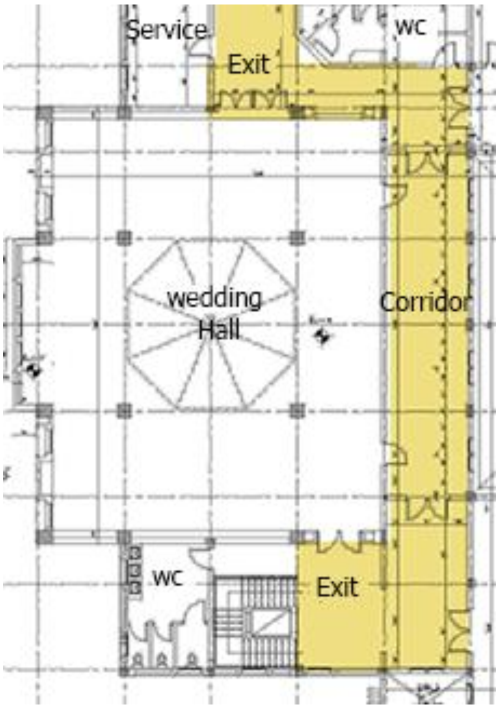

Figure 24: The addition of a corridor on the first floor to connect zones and reduce the surface area of the grand wedding hall in order to facilitate access to all stairs. [researcher]

4.2.4. Determining the general requirements for the exit discharge.

It was ensured that no more than one exit lets out to one exit discharge, and that it leads directly to the outside of the building.

4.2.5. Determining the minimum number of exits.

Doors have been increased to fulfill the requirement of two exits for spaces of more than 60 people (2 doors for the wedding hall, women's prayer hall and women celebration hall on the ground floor) (fig25,26).

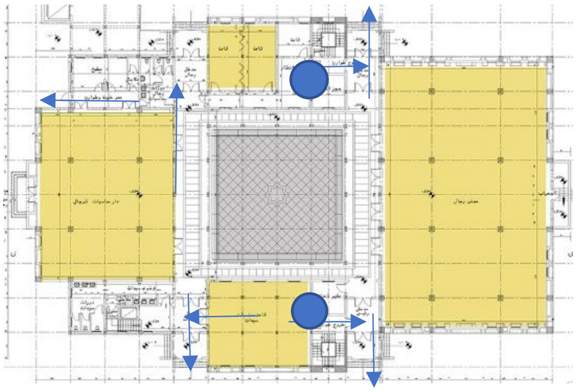

Figure 25: The large spaces on the ground floor, to which doors have been added to comply with the number of exits required by the code. [researcher]

Figure 26: The addition of a woman celebration hall with two separate exits in the hall. [researcher]

An external staircase was added to meet the code requirements of three stairs for the building, because the total occupant load for the first floor exceeds 600 persons, it is 700 persons (fig27to30).

Figure 27: Adding a concrete wall staircase to comply with the total widths of the required stairs. [researcher]

Figure 28: The finished external staircases with a width of 3.30 m to meet the code requirements. [researcher]

[4] Automatic sprinklers should be used in spaces with more than 300 occupants load.

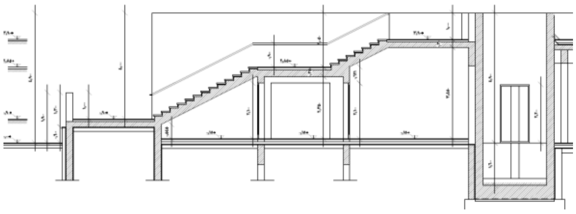

Figure 29: An illustrative section of the external staircase. [researcher]

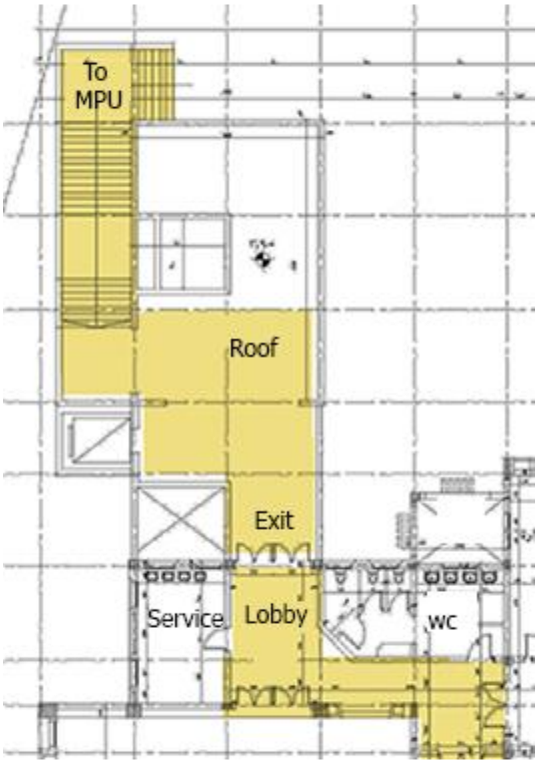

Figure 30: The first-floor plan showing how the wall staircase is directly connected to the wedding hall exit. [researcher]

4.2.6. Distributing and spacing of exits

It was ensured that the exits (stairs / doors) were so well distributed that occupants can walk in opposite directions, without exceeding the maximum travel distance, and that the distance between any two exits in the floor area is not less than the half of the larger diameter of the floor, with a minimum of 10 meters.

4.2.7. Calculating the exits widths.

The total occupant load for the first floor is 700 people, which requires a total staircase width of 6.60 meters, which in turn necessitates the addition of an external staircase with 3.30 meter wide to comply with the code requirements.

4.2.8. Calculating door widths.

Three spaced-out doors with a total width of 5.20 meters divided into 3.2 m for the door in stairs direction, and 2.0 m for that in corridor direction- were added to the wedding hall.

The rest of the doors widths were checked so that the exit unit fulfills a capacity of 110 persons on the ground floor and 75 persons on the first floor.

5. RESULTS

- The code requirements can be applied on existing buildings through the reference matrix formulated by the study at hand in order to achieve human safety and reduce hazardous consequences of code violation.
- Through the application of the matrix of readjusting the design of the existing buildings to fulfill the requirements of the life safety Code, the study has come out with the following results:

First: Buildings Classification according to occupant type.

- Spaces with a specific occupant load of 1m^2 are to be identified, distributed and spaced out, rather than grouped, in the ground floors
- Use of spaces should be adjusted to ensure the separation of buildings category (F-1) from the assembly occupancies category.

Second: Determining the total occupant load.

It is possible to move some walls to reduce space areas to less than 600 or 1000 persons in order to minimize the number of exits.

Third: Determining the maximum limits for the travel distances and the dead ends.

- Opening corridors and paths to maintain the travel distance of 35 meters and the dead ends of 6 meters.
- The possibility of enlarging some spaces to reduce the length of the dead ends.

Fourth: Determining the general requirements for the exit discharge.

- All exit discharges should lead to a public street or a safe open space approved by the competent authority.
- Half of the staircases should discharge directly to outside of building with the provision of water sprinklers in case the exit discharge distance exceeds 15 meters.

Fifth: Determining the minimum number of exits.

- Adding concrete external staircases to make up for the lack of stairs in case the code requirements are not applied.
- the necessity of having four exits in case occupancy is more than 1000 persons, and three exits if the occupancy is more than 600 and less than 1000 persons, and two exits for less than that.

Sixth: Distribution and spacing of exits.

Ensuring that the distribution of exits is more than 10 meters to match the building diameter.

- Adding doors in opposite sides to ensure the escape of persons in opposite directions.

Seventh: Calculating the exits widths.

- Reducing the occupant load of spaces by changing building use and reducing the area of some spaces, especially those with a specific occupant load within the range of 1m^2, hence reducing the widths of corridors and stairs.
- ensuring that the total width of stairs is 8 mm per person in above ground floors, 13 mm per person for underground basements, and 5 mm for doors leading to the stairs.

Eighth: Calculating doors widths.

- Check that in case of spaces with more than 60 people occupant loads, doors are to open to the outside of the building

- The investigation and analysis of existing buildings or those in the design stage shows clearly that the Life safety Code can be applied in a way that increases the efficiency of the building use. The analysis also shows the importance of checking the code requirements which, in the study at hand, successfully led to readjusting the design of both the Faculty of Engineering building at the Administrative University and the Aasia Mosque building in the Fifth Settlement.

6. RECOMMENDATIONS

The study recommends the following:

- Emphasizing the importance of applying the Life Safety Code in all buildings.
- Setting strict obligatory requirements linked to issuing building licenses with a more precise check of the code implementation.
- Integrating the life safety Code as a major course into the educational curricula of the Faculties of Engineering.
- Raise the awareness of the engineers, owners and society at large on the importance of applying the code to protect human lives, by holding specialized training courses.

7. CONCLUSION

Applying the life safety code to readjust the design of existing buildings is one of the most important factors for human safety and protection from fire hazards. The application of the concluded readjust matrix from the initial design stages to the existing buildings plays a principal role in this regard.

References

[1] The Egyptian Code of Principles and Implementation Conditions for Protecting Facilities from Fire - Part One, Ministry of Housing, Utilities and Urban Development, National Center for Housing and Construction Research, Edition of 2015, Arab Republic of Egypt.

[2] The Egyptian Code of Principles and Implementation Requirements for Protecting Facilities from Fire - Part Three - Fire Detection and Warning Systems, Ministry of Housing, Utilities and Urban Development, National Center for Housing and Building Research, 2015 Edition, Arab Republic of Egypt.

[3] The Egyptian Code of Principles and Implementation Conditions for Protecting Facilities from Fire - Part Four - Fire Extinguishing Systems, Ministry of Housing, Utilities and Urban Development, National Center for Housing and Building Research, 2007 Edition, Arab Republic of Egypt.

[4] M. Aboul-Ela, Architectural Preliminary review Report to Verify the Requirements of the Design Foundations Code to Protect buildings from Fire for the Buildings of the Faculty of Engineering - Fayoum University, June 2017, Arab Republic of Egypt.

[5] M. Aboul-Ela, review Report of the International University Project - Administrative Capital for Phase One, October 2018, Arab Republic of Egypt.

[6] Egyptian Code Draft for Safety Requirements for Multipurpose Facilities - Garage Code, National Center for Housing and Building Research, 2006, Arab Republic of Egypt.

[7] Standards and requirements for the validity of school sites and buildings - basic and secondary education schools in existing cities and villages, the General Authority for Educational Buildings, Research and Studies Department, 2018, Arab Republic of Egypt.

[8] Architectural graphic standards, (2000), Student edition, an abridgment of the ninth edition, John wiley &sons, Inc., Canada.

[9] International building code (IBC), International code council, Inc., 2012, USA.

[10] https://alarab.news Fire devours the buildings of culture in Cairo and hides evidence, 6/18/2018.