



Demolition or Restoration: A Case Study

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The decision of whether to repair (restore) or demolish-and-reconstruct a severely damaged building is not always obvious. Such decisions require not only regular inspection and design calculation, but rather long experience and practical judgment that needs to consider safety, serviceability, economy, and local conditions and constraints. In the case of Al-Amin Mosque in Gaza which was severely damaged during the war in July of 2014, two assessments were made. The first assessment classified the building as severely damaged and recommended the total removal of the building and reconstruction. However, another thorough investigation considering previous experience with similar cases and local conditions and constraints concluded the possibility of repairing and restoring the building. A cautious repairing program was successfully adopted which saved time and cost.

Keywords: Demolishing; restoration; reconstruction; repairing; strengthening; building damages; damage assessment; reserved strength of concrete buildings.

1. INTRODUCTION

Natural disasters and wars may lead to large scale impacts on life, property, social and cultural relationships. Disasters and their adverse impacts set societies back decades and leave

them vulnerable to physical, social, and economic hardships. This may inhibit large sections of the affected society to resort to the basic levels of life, let alone develop on par with the rest of the nation.

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Gaza Strip is a small geographic area with a very high population density (4,822 Cap/km²) [1]. This area suffered three destructive wars between 2008 and 2014. During these wars, tens of thousands of buildings were damaged [2,3]. All types of buildings were targeted, including; residential buildings, schools, hospitals, mosques, factories, water facilities, sanitation systems, and roads. Some buildings were completely destroyed, while other buildings were partially damaged.

For those buildings that were completely destroyed, the decision was clear to “remove and rebuild”. But for buildings with partial damages, the decision is not always obvious. It depends on the level of damage and other factors that include, but are not limited to, economic, social, functional, and political factors. The level of damaged is usually classified in three categories: 1) Minor damage; 2) Moderate damage; 3) Severe damage. [4,5]

Based on common practice, buildings with minor damage can be used as usual, but require minor repairs. Buildings with moderate damage, may still be used, but with caution during repair works. Those building which are classified as severely damaged cannot be used before proper repairs are completed. However, a decision of whether to repair (restore) or demolish-and-reconstruct a severely damaged building will first need to be assessed. Assessment of damaged building has been discussed by many researchers. Ireland and Koerth [6] discussed the structural assessments of existing buildings. The UCL Policy Briefing – June 2014 [7] Bonnie Dong [8] discussed the factors affecting such decisions which may include economic, social, and environmental factors. Such decisions will involve trade-offs between different objectives and values.

The following is a summary of the factors which may influence the decision of repairing or demolishing-and-reconstructing a severely damaged building:

- A. Safety of the building: Which is related to the structural system and to what level the strength of the main supporting system is affected, and the possibility of resorting the integrity and the original strength of this system.
- B. Serviceability of the building and the possibility of restoring the required level of service including functional, aesthetic and architectural properties.

- C. Feasibility of the restoration work as compared to demolition and reconstruction. This factor will also consider the age and the original condition of the damaged building and the expected remaining lifespan.
- D. The energy and carbon implication of demolition and reconstruction as compared to restoration and refurbishment works.
- E. Local conditions and constraints; such as political, social, economy, and availability of construction materials.

These days the local conditions in Gaza have an enormous influence over all other essential factors. The struggling economy and the shortage of construction materials due to the long lasting Israeli blockade have meant people in Gaza are sometimes willing to give up or lower the standard level of serviceability, and sometimes may accept the risk of compromised safety measures.

The case of Al-Amin Mosque is one of many buildings that were severely damaged during the last war on Gaza in 2014. The decision of whether to repair or demolish the building was assessed by two different engineering committees. The first assessment report concluded that the building should be demolished and reconstructed. In another assessment by a different committee, it was decided that the building can be retrofitted.

This paper will discuss the two assessment reports and the proposed retrofitting technique.

2. A CASE STUDY OF AL-AMIN MOSQUE

2.1 Description of the Building

Al-Amin Mosque was first constructed in 2005 in the south-western part of Gaza City. The building is made of reinforced concrete skeleton structure with infill walls. The foot print of the building is 550 m². The building consists of three levels; basement floor (550 m²), main floor (550 m²) and mezzanine level (220 m²). Like most other buildings in Gaza, this building is constructed of reinforced concrete skeleton structure (footings, columns, and slab with average span lengths ranging between 6-8 meters). Exterior walls and partitions are made of concrete hollow block. The external façade is covered with natural (Jerusalem) stone.

2.2 Missile Attack on the Building

Like many other buildings in Gaza, Al-Amin Mosque was attacked during the war in July of 2014 by Israel. The building was hit by 3 or 4 missiles weighing about one ton each on July 30, 2014. Two missiles didn't explode and were found buried beneath the building, while the

other missile(s) exploded and caused severe damage to the building. As can be seen in Figs. 1, 2 & 3 the explosions occurred in the basement levels. Due to the explosion pressure, the main floor slab was lifted and bent upward causing tension cracks in the middle columns. Most exterior columns, except corners, were damaged and bent outward.

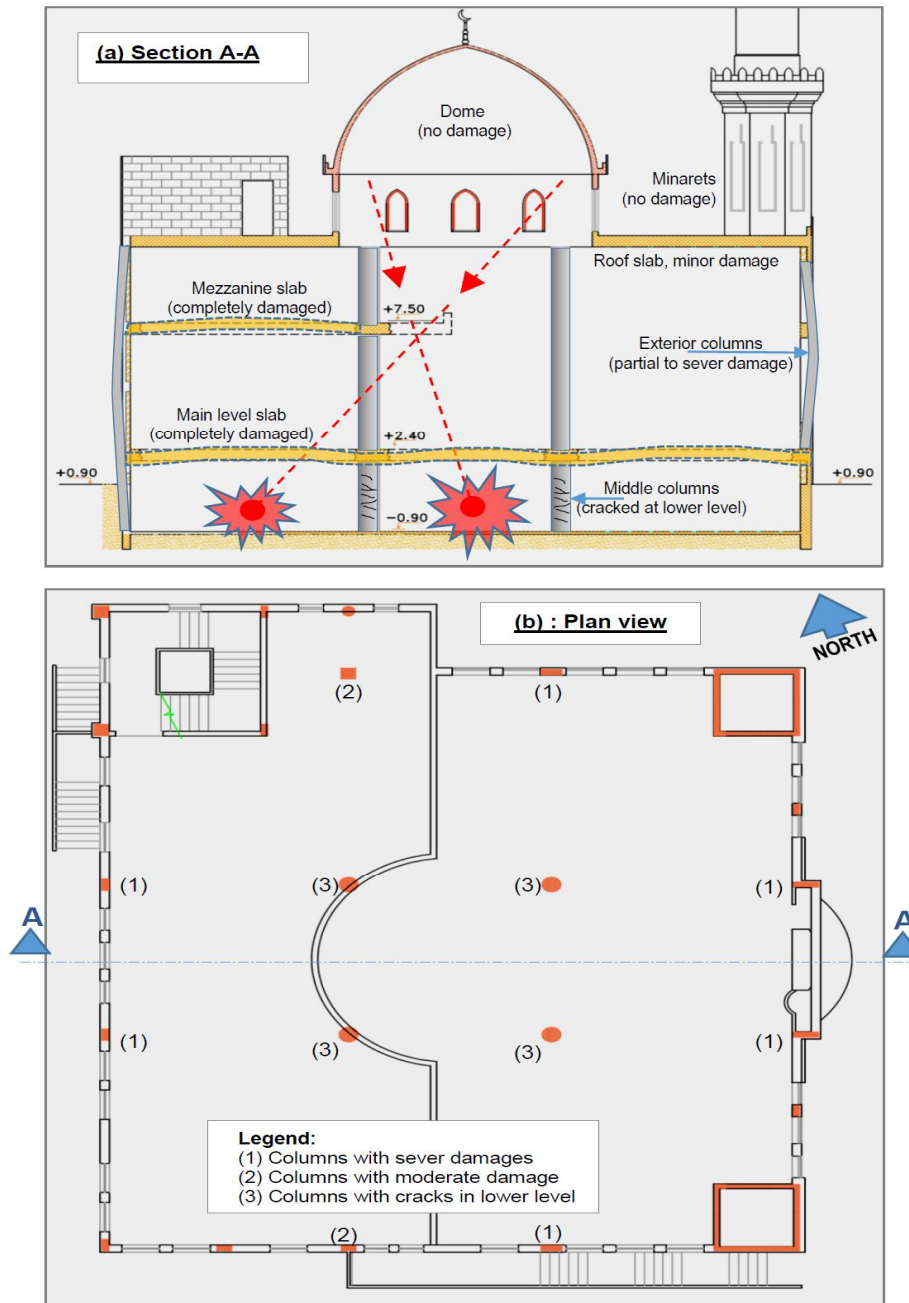


Fig. 1. Plan and section showing the locations of explosion and the damage



Fig. 2. Damage to Al-Amin Mosque- outside photos



Fig. 3. Damage to Al-Amin Mosque- inside photos (before and after removal of debris)

2.3 Observations

Based on visual inspections, the main floor slab was totally damaged, the mezzanine slab was severely damaged, and almost all columns were partially or totally damaged. However, the main roof slab appears to be in good condition except for two small holes (the missiles' entry holes). The two minarets and the dome are intact. In the basement level, the external earth retaining walls are generally in good shape with minor cracks at different locations. The foundations seem to be intact. The overall skeleton of the building appears to be integrated in spite of the severe damage to the main supporting columns.

2.4 Condition Assessment

After the ceasefire was in effect on August 26, 2014, the Ministry of Public Works and Housing (MPWH) in Gaza elected several engineering committees to assess the damaged buildings. The MPWH committee assessed the Al-Amin Mosque as "severely damaged" and classified it as a structure to be demolished [9]. However, another assessment conducted by a committee headed by the author of this paper concluded that this building can be retrofitted. This decision is based on the following factors:

1. In spite of the severe damage to the main floor slab and several columns, there are other main components that remained in good condition and can be conserved such as; roof slab, dome, minarets, basement walls, foundations, etc.
2. The shortage of construction material due to the continued Israeli blockade on Gaza and the shortage of funds encourages creative solutions that aim to save time, money, and materials.

2.5 Building Integrity and Reserved Strength

The severe damage in the building and especially of the main columns, raised concern about the integrity and strength of the building. However, previous experience and studies have shown that these type of buildings possess significant amount of reserved strength i.e. when a column is fully or partially destroyed its load will be redistributed and transmitted by the other adjacent columns and/or walls. This phenomenon was demonstrated by several similar case studies; Elmezaini, 2005 [10] conducted a 3-D Finite Element analysis to demonstrate the reserved strength of a 6-story

building that sustained the damage of three columns on the first floor. Shihada 2011 [11] presented a study about the strengthening of a 16-story building that was severely damaged in a missile attack. Citipitioglu [12] demonstrated the reserved strength of a 6-story building in which three columns of the basement floor were totally damaged.

In the case of Al-Amin Mosque, the fact that the roof slab, the dome and the foundations remained intact and stable in spite of the damage of several columns, indicate that the building possess significant reserved strength. The stability of the building can be attributed to the following:

- The four corners (including the two concrete minarets), which remained intact, provided reliable support and maintained the integrity of the building.
- The brick walls provide additional (redundant) support which helped transmit the load of the broken columns.
- The reserved strength (overdesign) of the roof slab and beams helped in transmitting the load of the damaged columns to the adjacent columns and/or walls.

2.6 Cost Analysis (Repair and Restoration vs. Demolition and Reconstruction)

The decision of whether to repair (restore) or demolish-and-reconstruct a severely damaged building is heavily influenced by the total cost of each scenario. This is especially important in a city with a poor economy like Gaza. Therefore, a cost comparison study was conducted to compare the cost associated with the following two scenarios:

1. Repair damaged elements and restore the building to original condition.
2. Demolish and remove the entire structure and reconstruct a new building.

Tables 1 & 2 summarize the cost estimate associated with each of the two scenarios.

As indicated in Tables 1 & 2, the cost of repair and restoration is 40% less than the cost of the total demolition and reconstruction.

It is important to note that the building, before bombing, was only nine years old and was in a very good condition. Therefore, the deterioration factor was not considered in the cost comparison study. It is also to be noted that the cost estimate

Table 1. Cost of repair and restoration

Description	Unit	Quantity	Unit price	Total cost
Removal of damage/debris	LS	1	30,000	30,000
Temporary support	LS	1	15,000	15,000
Restore columns	LS	1	15,000	15,000
Main floor slab	m ²	220	550	121,000
Mezzanine slab	m ²	220	230	50,600
Exterior walls	m ²	700	220	154,000
Electric & HVAC	LS	1	60,000	60,000
Furniture	LS	1	30,000	30,000
Miscellaneous	LS	1	20,000	20,000
Total restoration cost of repair and restoration				\$ 495,600

Table 2. Cost of demolishing and reconstruction

Description	Unit	Quantity	Unit price	Total cost
Demolish & Remove building	LS	1	50,000	50,000
Foundation	m ²	550	150	82,500
Basement walls	m ²	300	150	45,000
Main floor	m ²	220	550	121,000
Mezzanine slab	m ²	220	230	50,600
Roof slab	m ²	220	550	121,000
Minaret	LS	2	50,000	100,000
Dome	LS	1	50,000	50,000
Exterior walls	m ²	700	220	154,000
Electric & HVAC	LS	1	60,000	60,000
Furniture	LS	1	30,000	30,000
Unforeseen	LS	1	20,000	20,000
Total cost of demolishing and reconstruction				\$ 884,100

in Table 2 is based on the assumption of complete demolishing including the basement walls and foundation even though they are in good shape. This is because complete demolition is normally executed using heavy machines and it would be difficult to keep the basement walls and foundations undamaged unless demolishing is done with light/hand tools and in this case, demolishing cost may increase. But, in any case, the first scenario (in Table 1) will remain cheaper.

4. RESTORATION PROGRAM

Considering the above mentioned factors and the results of the cost estimates, the local committee in coordination with the Mosque administrators has decided to go ahead with the repair and restoration solution and to avoid the demolition and reconstruction of the building as was recommended by the MPWH committee. The engineering committee has come up with the following restoration scheme program:

4.1 Phase-1: Restoring Damaged Columns to Secure Building Stability

1. Remove all debris and loose concrete or block elements and clean the area. This

task must be cautiously executed using light handheld tools and jack hammers to avoid strong vibrations which may impair the building stability especially with the damaged columns.

2. Install temporary supports for the existing roof slab and the dome. Provide more supports around the damaged columns and the main supporting elements to carry its full load.
3. Plant new columns, as an additional support, wherever possible prior to removing and replacing damaged columns.
4. Remove and replaced damaged columns carefully in sequence and one at a time.
5. Once the damaged columns are replaced and the roof slab is secured reconstruct the main floor and the mezzanine slabs.

4.2 Phase-2: Reconstructing the Damaged Slabs and Walls

6. Remove the remains of the damaged main floor slab and reconstruct a new slab.
7. Remove the remains of the damaged mezzanine floor slab and reconstruct a new slab.
8. Remove all damaged wall partitions and other non-structural elements and rebuild with new walls.

Repair works have started in April 2015 (about 9 months after the bombing). All side columns have been replaced, and the middle columns were strengthened by jacketing. Fig. 4 shows the

arrangement of the temporary supports. Fig. 5 shows the replacement of columns. Typical details for columns and beam repairs are shown in Fig. 6.

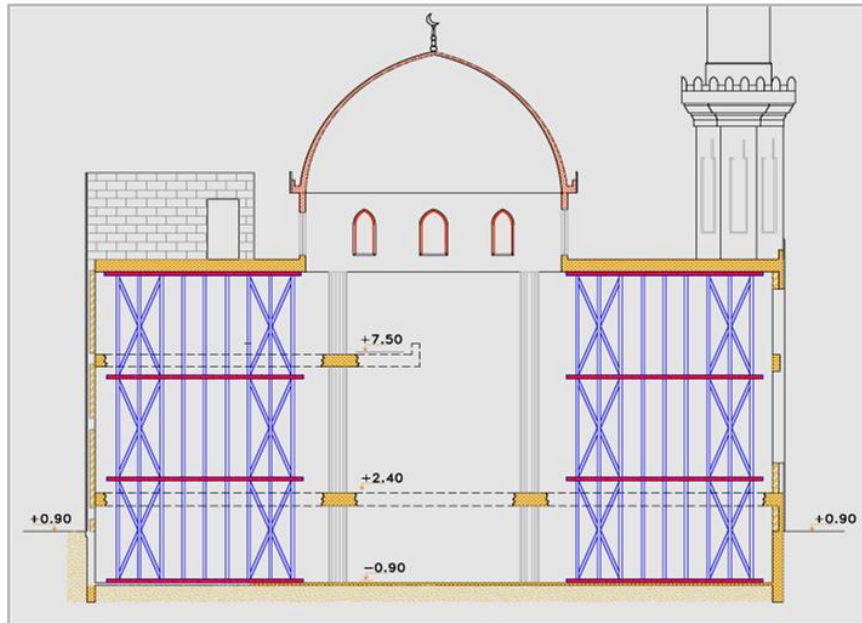


Fig. 4. Temporary support



Fig. 5. Replacing damaged columns

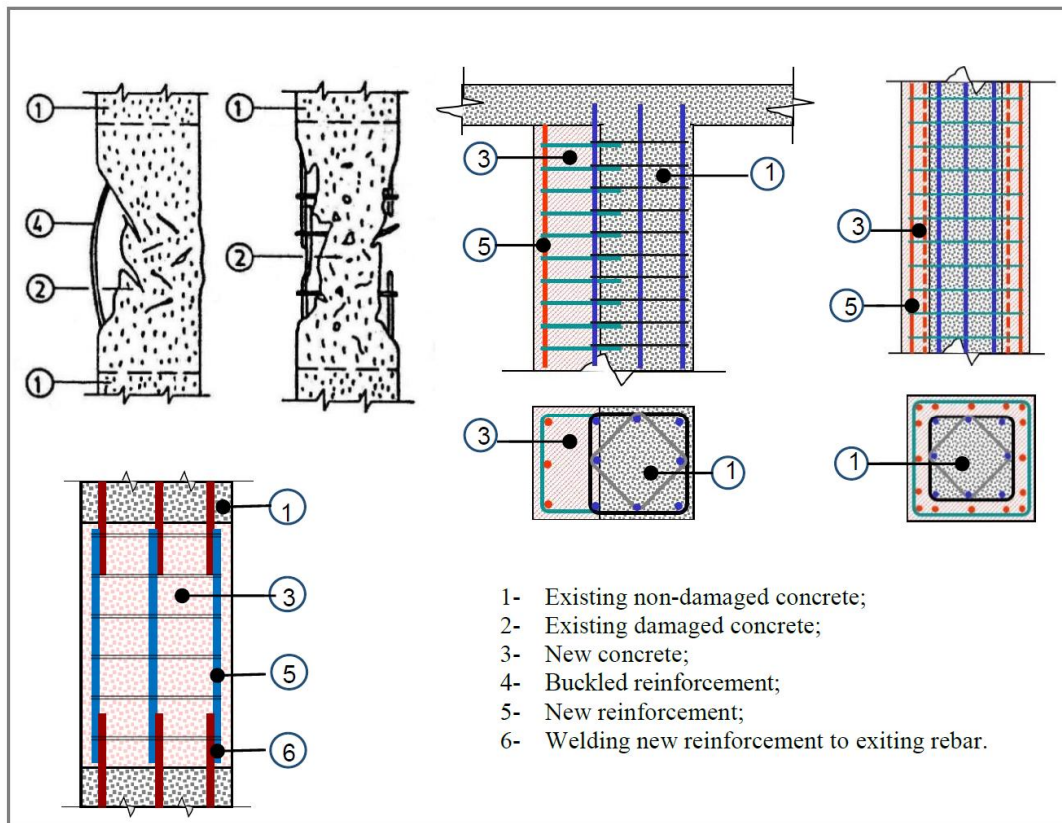


Fig. 6. Details for columns repairs [13,14]

5. SUMMARY AND CONCLUSION

Al-Amin Mosque was targeted by the Israeli air force missiles during the war on Gaza (July 2014). Large portions of the building were severely damaged, including main slabs and columns. However, the overall skeleton of the building continues to maintain its integrity.

The decision of whether to repair or demolish the building was assessed by two different engineering committees. The first assessment report by the MPWH committee concluded that the building should be demolished and reconstructed. However, another assessment with a more thorough investigation concluded that this building can be retrofitted. This decision was based on previous experience with similar cases considering the reserved strength of this type of buildings. The decision was also based on local conditions and constraints.

A repairing program that consists of two phases was planned. Phase-1 (restoring damaged columns to secure building stability) was successfully executed. Phase-2 including complete restoration is in progress.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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