AL-BUKHARIA FIRE
Urgent Rehabilitation Works

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Abstract*:** The paper presents an overview of the urgent strengthening and repair works carried out for ***Al-Bukharia downtown market, the oldest and the most famous market in Amman / Jordan, after a severe fire in August, 2009. In-situ evaluation/inspection revealed several architectural damages and vast commercial losses, on one hand, and a substantial loss of strength of many super-structural elements, on the other. Some internal ground floor columns and a skylight adjoining slab were found in rather bad structural condition, similarly, stone facades overlooking the internal skylight exhibited excessive spalling and sloughing off. These defects were considered very serious as they could endanger the safety of the whole structure. Consequently, immediate structural upgrading interventions and architectural rectification/decorative actions were decided to enhance the overall condition of the market with the intention to bring it back to service in less than one-month time. The paper will focus on showing different types of damages caused by the fire, their extent and assessment, and finally, the appropriate options, strategies and techniques selected for a successful rehabilitation. An experienced and qualified contractor was employed for the job and a qualitative approach for Quality Control/Quality Assurance (QC/QA) was implemented during repairs.

1. Introduction

In the middle of the night of the 5th of August, 2009, afire has started at "Al-Balabseh Market" then spread into "Philadelphia Market" and continued for about (10) hrs. before it was extinguished**.**

Fortunately, there was no life losses or injuries, but the damages within the two markets and their contents were substantial, associated with further indirect economic losses due to closure.

Also amazingly, the fire did not spread into the adjacent "AL-Bukharia Market" despite it was unconsciously, but reasonably, given its name, since AL-Bukharia Market is the oldest (established in 1942) and the most famous market in Amman-Downtown Fig.(1). Therefore, the sad incident gained both; public sympathy and authority attention.

Fig. (1)

2. Complex Salient Features

2.1 Location: Amman-Downtown; main/central commercial district; opposite to Al-Hussainy Global Mosque – king Talal Street.

2.2 Year of Construction: Before 1942

2.3 Description: Two adjacent buildings containing three markets [Fig(2)]:

***Al-Bukharia Market*:** Occupying the whole area of the ground floor of the "Northern Building".

Philadelphia Market: Occupying the upper (first and the second floors) of the Northern Building; i.e. above AL-Bukharia Market.

AL-Balabseh Market: Occupying the three-story "Southern Building", which has a large central skylight surrounded by stone wall facades with windows at upper floors.

Fig.(2)

3. Structural System

Vertical Elements

The vertical structural system of the two buildings is basically an R.C columns, and basement walls (western side of the ground floors-up to back street level) with external load bearing masonry stone walls and internal infill brick walls (partitions).

Flooring System

The floors are mainly R.C ribbed and solid slabs supported on drop beams.

Some of the upper floors of AL-Bukharia Building was made of glazed/steel slabs comprising glazed cellular fixed at their edges by a mesh of narrow steel plates supported on transverse steel I-Beams.

4. History of Fire

Fire Scenario:

Eyewitnesses and some of the stores owners maintained that the fire started at one area (unit) of the ground floor of AL-Balabseh southern building. The fire soon spread to its internal/central skylight and continue to other parts of the ground and upper floors. Finally, the fire got into the adjacent Philadelphia Market (i.e. to upper floors of the northern building) through the common windows overlooking the skylight of the southern building.

***Date of Fir* : 5/6-8-2009**.

***Duration of Fire*:** More than **(8)** hours.

5. RSS Investigation

Date: **10-8-2009**; Four days after fire.

***Duration*: One month** only before re-opening.

***Scope of Work*:**

Upon the fire, Amman Greater Municipality appointed the Royal Scientific Society (RSS) to make an immediate in-situ visual inspection and forensic structural fire assessment and evaluation of the two affected buildings, along with deciding all necessary safety measures.

Consequently, RSS was requested to present and supervise the execution of the urgent repair and rehabilitation works.

6. Visual Observations

6.1 Structural Damages:

It was evident from the initial visual inspection carried out by RSS team of experts that there was a serious problem relating to degradation of several parts of the complex due to the fire, combined/aggravated by the inherent structural weaknesses of the two buildings, attributed mainly to aging. Nevertheless, the overall integrity and stability of the two buildings were found satisfactory.

6.1.1 AL-Balabseh Market

Ground Floor:

Since the fire has started at the ground floor, most of severe damages and distresses were observed there:

1. Some stone cladded columns, particularly those located within the interior approaches, at edges of stores fronts, exhibited severe distress, burns, and explosive spalling, associated with low quality packing concrete [Fig.(3)]. Indicating significant strength reduction.

Fig.(3)

2. Excessive sagging (resulting from thermal expansion) of the slab of the corridor adjacent to the skylight (at its ground floor slab level) [Fig.(4)], accompanied with poor quality concrete and under-reinforcement with light rebars. Excessive crack formation was also observed within the slab soffit. Actually the slab "here in after, referred to as the ***Skylight Slab***" remained stable but was felt close to collapse, therefore temporary support (jacking) was immediately provided.

Fig.(4)

3. One mezzanine slab was significantly deflected (sagged), also the back staircase flight (leading to the upper floor) was extremely distressed.

Skylight Facades:

1. Severe burns and significant sloughing off and spalling of large portions of the skylight internal stone facades, Fig.(5).

2. Moreover, the upper faces of the skylight brick wall facades were burned.

Fig.(5)

6.1.2 Philadelphia Market

In general, steel portions suffered considerably more damage than those made of concrete in this market. Most of the fire structural damages were found within the (first and second) floors glazed corridor slabs. The defects included:

1. Broken cellular glazing , [Fig.(6)], associated with distortion of surrounding steel plate mesh.

2. Buckling and/or twisting of supporting steel I-Beams.

Fig. (6)

6.2 General Observations:

The following observations included almost all the stores, approaches and other utilities of the two abovementioned affected markets:

1. Out of plane thermal bulging or bowing of masonry block partitions, [Fig(7)].

Fig.(7)

2. Minor peeling to total loss of plaster of walls, ceilings, beams and columns.

3. Almost all contents (combustible good , mainly textiles) , decorations, finishes and painting were burned.

4. Considerable damage and irrevocable deflection of structural and decorative steel elements and associated metal appurtenances.

5. Many windows, doors, stores entries, and ducts were completely destroyed.

6. Most of AL-Balabseh Market ground floor tiles were crushed, mainly due to after- fire clearing out.

7. Large amount of fire debris; like charring wood, soften glass and plastic, molten PVC pipes, aluminum frames, damaged/destroyed false ceilings, partitions, panels, doors, windows,.. etc. was accumulated within the two markets, [Fig.(8)].

Fig.(8)

7. Safety Measures and Immediate Actions

1. Evacuation of the two buildings and separation from the surrounding occupied area by erecting safety barriers.

2. Supporting structural elements initially suspected as vulrnable to imminent failure or local collapse.

3. Demolishing and removing bulged or damaged block walls and partitions.

4. Dismantling and removing unfixed or hanging elements, false ceilings….etc.

5. Removal of disturbed and fractured stones, as well as, those expected to fall down within the skylight facades.

8. Assessment and Evaluation of Fire Damages

8.1 Literature Review:

8.1.1 General:

In general concrete structures have historically performed well in building fires, because concrete is non-combustible and has relatively low thermal conductivity, and provided that the concrete cover to the internal steel reinforcement remains in place during heating (i.e there is no cover spalling) heat flow to the interior of R.C element in fire occurs slowly. Moreover, the fire resistance of a concrete structure is frequently well above its minimum requirements and, because of the structural continuity present in most buildings, it is normally higher than is required for the structure to survive fires and be reinstated. As a result, structural failure (local or global collapse) of fire buildings is rare.

Reinstatement by repair will, therefore, nearly always be preferable to demolition and rebuilding. Reinstatement may require less capital expenditure than demolish and rebuilding, and may also produce a direct saving as a result of earlier occupation.

On the other hand, fire damaged structures can be brought back into use by removal and replacement of damaged concrete and internal steel reinforcement.
The larger the building and the more extensive the damage, the greater will be the probable need for complete replacement of some elements.
Partial structural damage and irrevocable deformation can usually be observed in concrete slabs, beams and columns due to differential thermal gradients and restraint conditions.

Lateral thermal expansion of concrete floor beams can result secondary moments and lateral shears on columns that where not designed for such forces.

Discrete cracking in regions not explicitly designed for the stresses and deformations can be also observed under the abovementioned conditions.

Cracking and spalling can be serve, particularly for elements with thin concrete webs and for slab soffits with low quality concrete.

8.1.2 Effects of High Temperature Upon Structural Materials:

The spalled and discoloured blackened concrete surfaces and exposed reinforcement generally apparent after a severe fire often present a picture which suggests an almost total disaster. It is, therefore, necessary to be strictly objective and to consider the effect of high temperature upon the properties of the materials concerned.

Compressive Strength of Concrete:

For temperatures up to 300 ºC , the residual strength of structural-quality concrete is not severely reduced. On the other hand, temperatures greater than 500ºC can reduce the compressive strength of structural concrete to only a small fraction of its original value and such concrete is unlikely to possess any useful structural strength.

Colour Changes in Concrete:

The colour of concrete after cooling frequently helps to indicate the maximum temperature attained. The intensity of the change of colour varies with the type of fine and coarse aggregate.

The (pink) colour at about 300 ºC which occurs with most siliceous gravel or sand aggregates is very important, as it coincides with the temperature below which residual strength is not significantly reduced.

At about 600 ºC the colour changes to (whitish gray) and then becomes (buff) at about 900 ºC. However, spatial temperatures greater than 900 ºC are frequent in buildings fires.

Transmission of Heat Through Concrete:

In a concrete member, only the temperature of the outside layers is drastically increased, and so the temperature of the internal concrete may be comparatively low. Nevertheless, the transmission of the heat in R.C structural members depends mostly on their shape, intensity of fire, type of aggregate and moisture content.

Elastic Modulus of Concrete:

A considerable reduction in elastic modulus occurs during a fire and after cooling. This may amount to (40%) after exposure to temperature of (300 ºC) or (85%) for (600 ºC). However, increased elastic deflection from this cause alone is unlikely to be significant in relation to other effects.

Spalling of Concrete:

Two main types of spalling can be recognized. Explosive spalling, appears to occur only for concrete with a limited range of moisture content. It generally occurs within the first (30) minutes of exposure to heat and proceeds with a series of disruptions, each locally removing layers of shallow depth.

Another type of spalling, often referred to as "sloughing off", is a non-violent gradual separation which occurs chiefly in columns and beams.

Cracking:

At high temperatures, the unrestrained thermal expansion of steel reinforcement is substantially greater than that of most concretes. This can lead to bursting stresses and cracking around the steel in heavily reinforced members.

Effects Upon Reinforcing Steel:

Significant loss of strength may occur while the steel is at high temperature such that only (50%) of the original yield strength remains at (550 ºC), with further reductions as the temperature increases above this figure. This loss at high temperature is usually responsible for any excessive residual deflection.

However recovery of yield strength after cooling is generally complete for temperatures up to about (700 ºC).

8.2 RSS Urgent Assessment:

An immediate and thorough forensic fire assessment has to be carried out with clear objectives:

1. Identifying and assessment of damages.

2. Deciding the best methods for urgent repair/strengthening works.

3. The markets have to be re-opened as soon as possible to avoid additional indirect economic losses. Therefore, repair techniques and procedures should be effective and fast.

Based on experience and field inspections and observations, RSS team was able to identify the serious damages caused by the fire without the need for performing further elaborate and time consuming laboratory testing or analysis.

One the other hand, the team concluded (based on similar previous expertise and available literature review), that despite of the losses of strength of some structural elements, the affected buildings were still stable and capable of sustaining normal operation/ occupation loading. Yet, they need to be repaired and strengthened to accommodate specific structural and durability requirements.

It is noteworthy to emphasize here that, so far, about five years beyond job completion date, the satisfactory performance of the two repaired structures has proved the correctness of prompt conclusions and decisions taken by RSS investigation team.

9. Rehabilitation and Repair Works

9.1 Strategy for Rehabilitation:

Appropriate actions were suggested to prevent future buildings' local or global failures. Mass scale replacement was discouraged. Instead, it was decided to carry out localized strengthening, repair, and restoration works including:

1. Strengthening of distressed structural elements. Priority was assigned to columns.

2. Stiffening of deflected or sagged slabs.

3. Replacement of damaged steel slabs and elements.

4. Repair of non-structural elements.

5. Superficial repairs, including plastering.

6. General restoration works, such as, tiling, finishes, painting, carpentry, steel/aluminum/gypsum decoration..etc.

7. Complementary sanitary works, including plumbing and replacement of some drainage pipes.

8. Miscellaneous electrical works and fire alarm device installation.

9.2 Preparations and Clean-Out:

In addition to demolishing, removal, dismantling and temporary supporting works initially carried out as part of the urgent actions and safety measures [listed in Sec. (7) above], the following preparations and cleaning works were also performed:

1. Removal and cleaning of fire debris.

2. Removal of delaminated /detached plaster, crushed tiles and spalled/weak/loose concrete segments.

3. Dismantling worn false ceilings and decorations.

4. Thorough cleaning of stone façades by Sand/ Grit-Blasting.

5. Cleaning of surfaces of ceilings, walls and floors by Water-Jetting.

9.3 Work Execution:

9.3.1 Major Interventions:

Jacketing of Columns:

The apparently defected ground floor columns at AL-Balabseh Market were jacketed with rich reinforced concrete sections. An epoxy resin was employed for fixing the shear anchors (dowels), as shown in Fig.(9).

Fig.(9)

Skylight Slab:

The excessively deflected and deteriorated "Skylight Slab" at AL-Balabseh Market was provided by an independent/bypass composite system [Fig.(10)] comprising an underneath R.C slab on corrugated steel sheets carried by steel I-beams and H-columns supported on R.C pedestals.

This system was chosen for fast construction, on one hand, and to enhance the overall structural condition of the surrounding elements, on the other

Fig.(10)

Mezzanine Sagged Slab:

The sagged mezzanine slab at the ground floor of AL-Balabseh Market was stiffened with an R.C column with top crown/panel located at slab mid spans (center). The new column was supported on R.C spread footing.

Back-Stair Flight:

The weak flight of the back entrance stair of AL-Balabseh Market (located below ground floor slab level) was strengthened with a short/stiff R.C cantilever beam extended /framed from the top of the underneath new column jacket.

Skylight Facades:

The extremely affected AL-Balabseh skylight masonry/stone facades were decided to be repaired with multi-layer reinforced (with wire mesh) plastering, as shown in Fig.(11).This technique was chosen in lieu of reinstatement with similar stone cladding since the (re-cladding) slow process will delay the progress of the whole work; an option that we didn't have in our urgent case. Yet, plastering didn't impair or obscure the overall original architectural pattern of the building as it is applied only for internal facades

Fig.(11)

Glazed Slabs:

The damaged glazed/steel slabs at Philadelphia Market were completely replaced with a more efficient R.C solid slabs carried by corrugated steel sheets. The existing supporting steel I-beams (transoms) were further enhanced by additional (alternate) new I-beams, [Fig.(12)].

Fig.(12

9.3.2 Miscellaneous Repairs and Complementary Works:

1. Initially demolished block walls were rebuilt. Also partially damaged or removed partitions were completed/rectified. Plastering was also implemented.

2. Re-Plastering of all burned, delaminated or spalled plaster. Special High- Bond Cement plaster was employed, particularly, for ceilings, Fig.(13).

Fig.(13)

3. Re-Jointing/Re-Packing deteriorated and/or loose jointing of stone courses at AL-Balabseh Market, utilizing whitish colour cementitious non- shrinkage bonding mortar.

4. Providing new tiles for the internal approaches/corridors of the ground floor of AL-Balabseh Market.

5. Painting to complete surfaces of exposed new or repaired elements, utilizing weather resisting paint (Synthetic Enamel or Acrylic Emulsion, as applicable).

6. Damaged windows and doors were dismantled and changed.

7. Leaking or broken pipes, drains, etc. were replaced. Additional electrical lines and fittings, as well as, fire alarm devices were also installed.

In parallel, the owners of commercial stores were allowed to start their own complementary restoration/decoration works, including, cabinets, shelves, mezzanines, gypsum boards, false ceilings, lighting and decorative fixtures…etc.

9.4 Work Completion:

The whole rehabilitation and repair works were completed within the targeted time (30 days) coincidence with the Holly Ramadan Month, where the activities continued all days and nights until the reopening ceremony on **16/9/2009** ;
Fig.(14).

Fig.(14

10. References:

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