Baghdad missile-damaged building brought back to life

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Introduction
The Al-Mansour Building (Figure 1) in Baghdad, Iraq, is a seven-storey office building designed and constructed by a consortium of three Japanese companies in 1982. Later, it was one of many buildings damaged in the 2003 war, when it was targeted by five smart missiles which drilled through its roof. Two of these missiles exploded within the second to third floors, while the other three continued punching through successive floors down to the basement, where they exploded. Severe damage was caused (Figure 2).

Rehabilitation proposal
Following the war, many investigations had been conducted and proposals for repair submitted, but none were specific, practical or economical enough to be adopted. In late 2013, the author made a preliminary site visit, followed by a detailed survey, which recorded the damage to each steel member. This work was complemented by collation of all available technical reports and the original design calculations.

The explosion of missiles within the second to third floors of the building’s interior resulted in heavy damage to the surrounding area; the most severe was inflicted on the two main columns. These were virtually shredded, to an extent that prevented them from effectively supporting floor beams. Many girders and joists, along with their concrete floor panels and steel decks, were also damaged in degrees ranging from slight to heavy.

The main strategy for rehabilitation was therefore removal of the two damaged columns followed by their replacement. To accomplish this, it was necessary to inset some temporary steel to bypass the damaged columns, and use this to transfer load down from the fourth to the first floor, and then to remove the damaged steel and replace it.
Based on the detailed site survey of the damaged steel frame, and working with the original design calculations, a structural model was prepared using STAAD.Pro. All existing components were represented whether damaged or not, but their actual condition was modelled. For example, some members were only partially damaged through their webs or flanges, so reduced section properties were considered appropriate. Techniques used included decreasing sizes or thicknesses, or introducing suitable intermediate releases to simulate any weakening that had taken place. Several structural models were prepared for the building to cover:

- the theoretical as-built steel frame
- the existing damaged steel frame
- the steel frame after eliminating the most heavily damaged members (i.e. from the first to the fourth storey)
- the steel frame after introducing a supporting frame

**Repair work**

The restoration plan called for the introduction of a supporting steel frame through the void made by the explosion (three stories high), starting from the first floor and rising up to the fourth floor, to replace the load-carrying capacity of the damaged main columns (Figure 5). The supporting frame columns were laterally braced with square tubes at each floor level. Then, at the frame top, two hydraulic jacks were inserted to lift the upper building stories. This was necessary in order to introduce gaps at the contact points between the top of the damaged columns (i.e. above first-floor level) and the bottom of the new columns erected above, so that a steel plate could be inserted.

"Given the amount of column damage in particular, a redistribution of forces had clearly taken place"
The lifting operation was performed in early 2015 and the upper (old) columns with their floors were lifted vertically by about 12mm at each of the two contact points using a hydraulic jacking force of 1100kN. A 12mm thick plate was then inserted between the column bearing end plates, and hammered in, before the pre-designed connection was fitted and welded. The last step was to release the hydraulic jacks so that the new replacement main columns became active and carried their share of load, restoring the integrity of the framing system.