Seventh Canadian Masonry Symposium
McMaster University
Hamilton, Ontario
June 4-7, 1995

PERFORMANCE OF MASONRY ELEMENTS UNDER FIRE AND SHELLING DURING THE GULF WAR

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ABSTRACT

In August 1990 Iraq invaded Kuwait and occupied the country for seven months. During this time many buildings were subjected to direct shelling or fire, or both, causing extensive damage. Several case studies are presented to show the performance of masonry elements under such conditions. It was found that the masonry walls used in Kuwaiti construction were very resistant to the damage inflicted. Due to their high resistance to fire, they prevented fire from spreading to adjacent rooms and buildings. In buildings with a reinforced concrete skeleton, after the loss of supporting members, infill masonry walls acted as wall-bearing elements and kept the building standing, thus saving lives and enabling repair work to be carried out later. Concrete structures with infill masonry walls showed considerable resistance to both fire and direct shelling, while the resistance of steel structures was very limited.

INTRODUCTION

In Kuwait the great majority of buildings are built using a reinforced concrete (RC) skeleton with infill masonry walls. The walls are generally made of solid concrete blocks, their thickness varying between 10 to 15 cm. Such masonry walls, if they are for internal use, will be plastered with 1 to 1.5 cm of cement on both faces, then painted for final finish. If these walls are for external use, the inner face will be plastered and become part of a cavity wall with thermal insulation and appropriate external cladding. The different components of this system and the economic reasons for its dominance are explained in detail elsewhere (Fereig & Horn 1990). Thus the main use

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of masonry in Kuwaiti buildings is as infill walls in reinforced concrete skeletons.

In buildings where a long, clear span is required, as in showrooms or industrial buildings, an RC skeleton is no longer economical due to its own weight. The building system in use in these cases is a steel structure and is mostly pre-engineered steel frames with a metal deck and metal cladding

In the late 1970s and early 1980s, different attempts were made to introduce the reinforced masonry system to buildings in Kuwait (Fereig & Horn 1985) This was limited to residential buildings, which turned out to be less economical in their initial cost from the current system and their use, accordingly, became very rare. There are a very limited number of one- or two-storey buildings built using unreinforced masonry wall-bearing. These buildings were built before the oil boom in the early 1970s, but they are still standing and in use. During the Gulf War, some of these buildings were subjected to direct shelling, others to fire, or both. In a previous paper, an overview is given of the impact of fire and shelling in reinforced and unreinforced masonry buildings (Al-Khaiat, et al 1993; Fereig, et al 1994).

This paper examines the performance of masonry elements, which are the most widely-used system in Kuwait, i.e. RC buildings with infill masonry walls. The behaviour of steel structures under such abnormal loading is also presented.

REINFORCED CONCRETE SKELETON WITH INFILL MASONRY WALLS

The majority of cases investigated were for RC skeletons with infill masonry walls. They will be described under two headings, depending upon the damage sustained.

Under Fire

Due to the presence of the masonry elements and their resistance to fire, the fire damage was contained within the specific rooms in which incendiary bombs were dropped, and effectively prevented from spreading to the rest of the building. These elements thus acted as a buffer to prevent the fire from spreading. As well, the plaster acted as a fire-coat to limit fire damage to the structural elements. Figures 1 and 2 show a building from both inside and outside. The greatest extent of fire damage occurred within the building. Repair and rehabilitation of this building was economical since it involved only a clean-up operation and replacing the internal finishes. In some cases, such a fire damages the building's electrical and mechanical systems, which must then be replaced.

Under Shelling

Figures 3 and 4 show a building subjected to direct shelling, during which extensive damage was inflicted on the main structural elements such as columns and beams. Despite the loss of these supporting systems, a redistribution of load took place, in which the masonry walls assumed the weight of the floor slabs and kept the

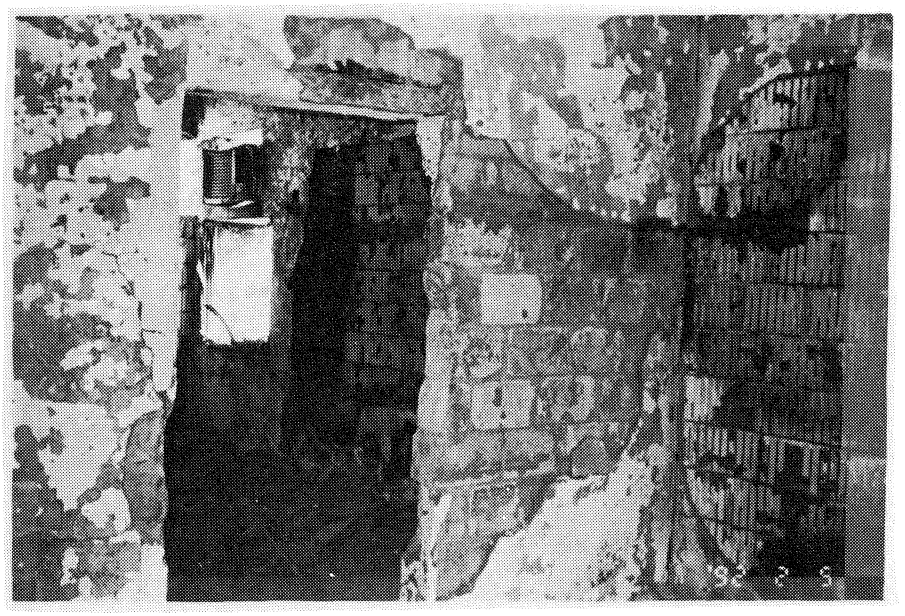

Fig. 1: Interior of Building that Suffered Extensive Fire Damage

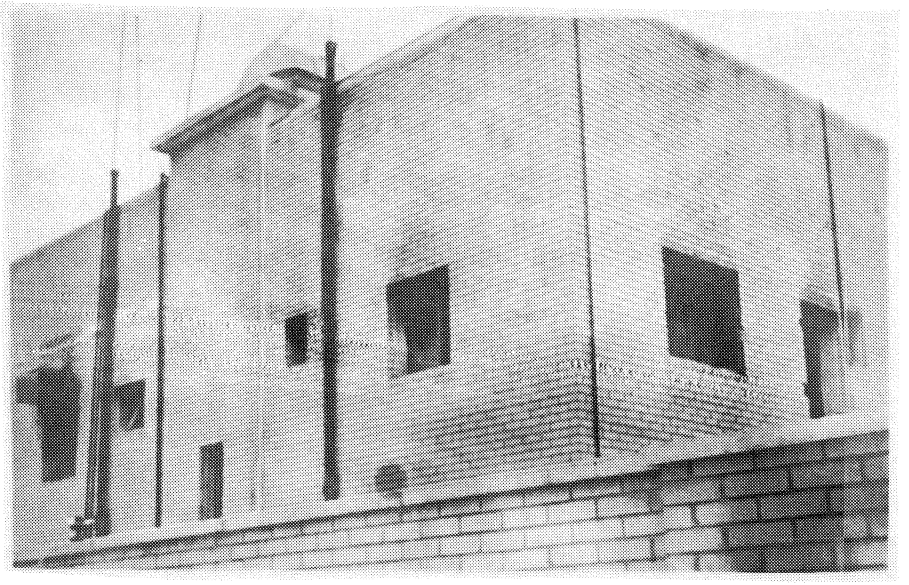

Fig. 2: Exterior of Building that Suffered Extensive Fire Damage
To Its Interior

structure standing, but with extensive cracking. Nevertheless, keeping the building standing made it possible to carry out repair work later, and save lives that otherwise would have been lost if the building had collapsed because of the loss of supporting elements.

Fig. 3: Building Subjected to Direct Shelling, where the Main Structural Elements Suffered Extensive Damage

Fig. 4: Another Building Subjected to Direct Shelling

STEEL STRUCTURES UNDER SHELLING AND FIRE

Steel structures are in common use in Kuwait, mainly for showrooms, exhibition halls and various industrial and commercial applications. There are very few masonry elements in such structures. After direct shelling and fire, these structures displayed considerable vulnerability in the extent of damage suffered. Figure 5 shows a large showroom where the main supporting frame came under direct shelling: after the main carrying system collapsed, the rest of the structure also collapsed.

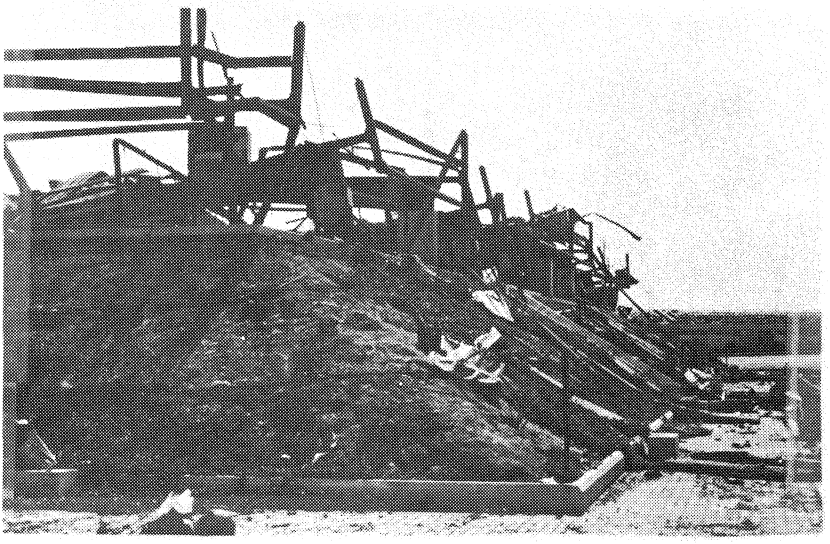

Fig. 5: Large Steel Structure, after Direct Shelling, Suffered Total Collapse

Similar behavior occurred for steel structures under fire: once the main supporting system collapsed, the rest of the structure collapsed also. Repair of such structures is not economically feasible; the only way to use the land is to demolish what is left of the building and then build a new structure.

RESISTANCE OF CLADDING AND ITS REPAIR

Sand-lime brick is the most commonly used cladding system in Kuwait. It is widely available at an affordable price. When such cladding was subjected to fire from inside the building, it withstood the heat, with no signs of stress. Figure 6 shows a house where this cladding system has sustained damage from shelling. The cladding system's resistance to shelling was remarkable, as can be seen in Figure 7. Repair of such cladding is done simply by replacing the damaged section, since the sand-lime brick is available locally and masons are available locally to carry out the repair. The time and cost of such operations were satisfactory and economical.

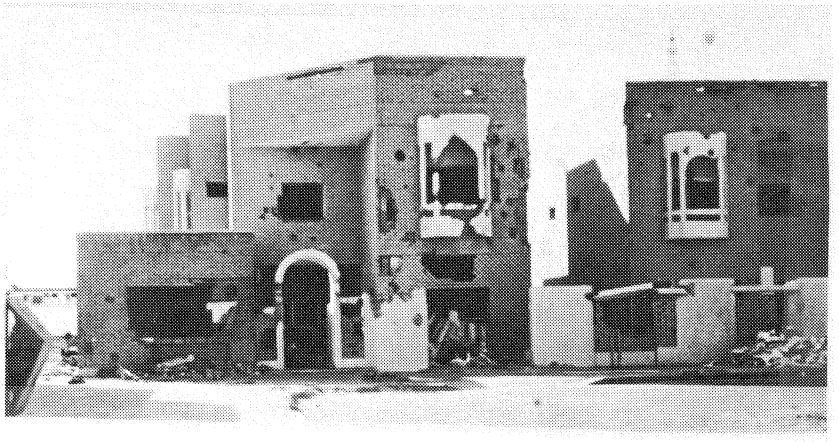

Fig. 6: House where Cladding System sustained Shelling Damage

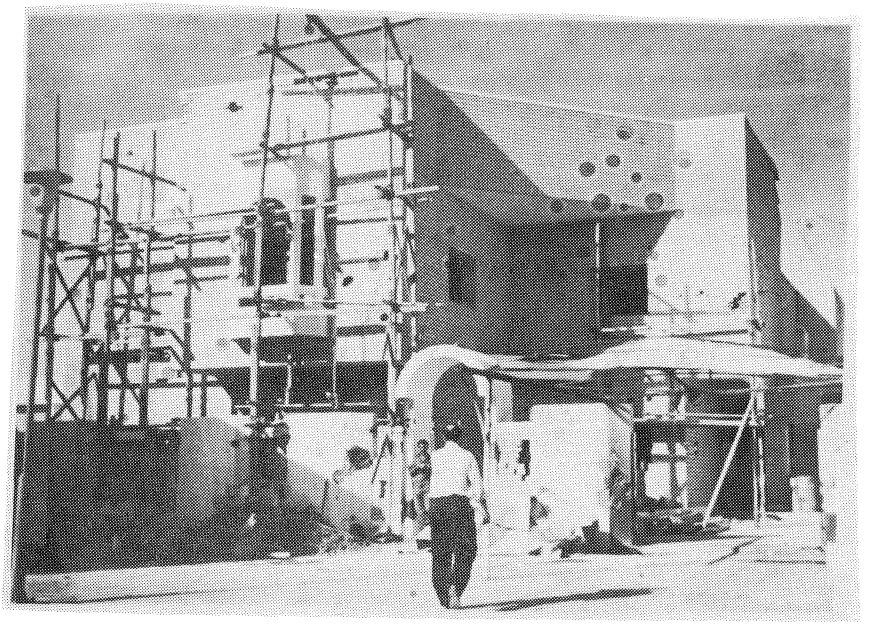

Fig. 7: Cladding System shows Remarkable Resistance to Shelling

SUMMARY AND CONCLUSIONS

The normal practice in construction of Kuwaiti houses is to use masonry walls, either infill or load-bearing. Such practices proved to be very useful under the circumstances, because they fulfilled the following two main functions:

Due to their higher resistance to fire, they prevented fire from spreading to adjacent rooms and buildings, and

After the loss of supporting members, masonry infill walls acted as wall-bearing elements and kept the building standing, thus saving lives and enabling repair work to be carried out later

Performance of steel structures, compared to masonry structures, was extremely poor under both fire and shelling, and the cases investigated had to be demolished and rebuilt since repair was uneconomical.

Masonry cladding withstood the internal heat of the building, with no signs of deterioration. It also sustained shelling damage. Repair was simple and economical.

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