

Construct in **STEEL**

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The collapse of the World Trade Centre Towers, New York

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The Council of the Australian Institute of Steel Construction and all members of staff are joined in profound sympathy for those affected by the tragic events in New York and Washington on 11 September, 2001. As an organisation committed to promoting excellence in the construction of buildings and other structures for the benefit of mankind, we have all been appalled to see modern technologies used in the hands of terrorists as weapons of mass destruction.

While the sight of two of the world's tallest buildings collapsing – each 110 stories high – has horrified all who have seen the images, it will be some time until the full story is uncovered by the detailed investigations currently under way. The American Society of Civil Engineers is contributing to this investigation, as indicated on their website which may contain answers to some of the questions people may wish to ask at: http://www.asce.org/emerg_document_pub.cfm

In the search to understand these tragic events, the media have reported comments by architects and engineers on the performance of the World Trade Centre towers in the face of the terrorist attacks. Possibly because of lack of understanding of the principles of fire engineering, some of these comments have been misleading, or otherwise inaccurately reported, suggesting that reinforced concrete structures would have performed better.

More will be learnt as the investigations proceed, but in the meantime a number of internationally respected specialists have agreed that the towers performed very well during the attacks. To fully appreciate this it is necessary to consider the extreme nature of each of the three abnormal loading events that occurred. It should also be noted that it is unreasonable to compare the performance of these towers with some notional concrete equivalent because an equivalent has never had to withstand such an attack: the hypothetically better performance is argued from silence.

Firstly the buildings were subject to violent impact as each aircraft hit with a force that would have collapsed most buildings. Some idea of the magnitude of the impacts is gained from the earth tremors they caused – measured at 0.7 and 0.9 on the Richter scale for earthquake intensity at a seismic station 34 kilometres from Manhattan. The significance of these values is that, unlike an earthquake that occurs at considerable depth in the earth's crust causing wide-spread seismic forces, these impacts were very localized, occurring several hundred metres above ground, before being transmitted through the structures to their foundations and into the subgrade. The fact that such large disturbances were measured at such a distance is testimony to the force of the impact.

The video footage clearly shows that although damaged seriously, the redundancy and ductility of the structures enabled them to continue to stand while many of the occupants made their way to safety.

As we can all no doubt vividly recall, the collisions of the aircraft with the buildings caused violent explosions as the fuel tanks, which contained 90,000 litres of aviation fuel on take-off, exploded like enormous Molotov cocktails. One specialist has estimated that the energy released during these explosions was about 35 times that of the impact of the aircraft with the buildings. Again, although the explosions clearly seriously damaged the buildings further and undoubtedly impaired the fire protection systems – which included fire protection of the structural steelwork systems and sprinkler systems – the buildings continued to stand. Again, the ductile and highly redundant steel framing for the structures served its purpose.

It is possible that the inevitable reversal of loadings caused by the explosions could have been even more devastating if reinforced and/or a pre-stressed concrete were used. Furthermore, depending on the actual structural configuration adopted the wider column spacings that would probably have

been employed in a concrete structure could have prevented the arching action that obviously occurred from doing so, leading to premature collapse of the buildings, possibly before many of the occupants could have escaped.

Photographs indicated that massive fires broke out simultaneously over a number of levels as a result of these explosions. Fire experts agree that it was probably these fires that eventually led to the collapse, critically reducing the very small reserves of structural strength. These hydrocarbon-fuelled fires were quite unlike any ordinary office fire. It has been suggested that the maximum temperatures reached would have been between 1000 and 1200 deg C, reached within seconds of the explosions. By contrast, an office fire might eventually reach a temperature of 1000 deg C over a period of 30 minutes to 60 minutes or more. All conventional structural materials would be overwhelmed by such a rapid increase in temperature.

If these high temperatures were sustained for very long after rising so rapidly, it is highly unlikely that a concrete structure could have performed any better than the fire-protected steel structure, as the intense heat would have caused moisture trapped in the concrete to expand rapidly, forcing the concrete to spall significantly. This would have seriously reduced the cross-sectional area of the members exposing the reinforcement to the full intensity of the heat. To resist such rapid temperature rises, the petroleum industry has learnt that concrete structures themselves need to be provided with appropriate fire-protective coatings where fireproofing against oil fires is required.

Typically, a multi-storey office fire, if not arrested, builds up over an hour or so and will possibly jump to the floor above. In such a case, the structural members are usually subject to intense heat from below only. The structural members in these fires however were engulfed in fire from all directions as it broke out over many levels.

It has been suggested that the rate of energy released in these fires was many times the magnitude in a typical office building fire. The power output that can be successfully quelled by a fire brigade is in the order of 10 megawatts, compared to the power of these fires that were in the order of hundreds, if not thousands, of megawatts. No fire-fighting system presently available in the world could quell such fires at this height in a multi-storey building.

As a rule of thumb, fire engineers assume that the fire resistance level of a structure in a hydrocarbon-fuelled fire is about half that of a conventional fire because of this rapid temperature rise. This would have meant these buildings, which it is believed had a two-hour fire resistance level, would have been expected to have remained structurally intact for about 1 hour, due to the effects of the fires alone.

As the massive fires surrounding the structural framing members continued, the fire-protective systems for the structure, which would have undoubtedly been damaged by the initial impacts and explosions, would have eventually ceased to fulfill their design function. By this time however, approximately 56 minutes for the southern tower and 104 minutes for the northern tower – many tens of thousands of people were able to escape. By this measure, although severely crippled by impact and explosions, the southern tower withstood the effects of the fire for as long as would have been expected due to the effects of the fire alone and the northern tower for twice as long.

While recommendations will undoubtedly be made as a result of these tragic events, they will probably relate to reducing the number of deaths by providing improved warning and communications systems, alternative means of redress, and fire refuges at various levels. It will probably be found that it is not economically viable to design a commercial building to provide protect against such terrorist attacks, or even against impact from such large aircraft.

Never-the-less, the relative merits of concrete and steel-framed service cores will no doubt come under scrutiny, possibly assisted by the findings of investigations into these collapses.

The real issue is that events of this nature have only a remote probability of occurring and the cost of totally protecting the community against them will probably prove to be unacceptably high. This

is an extension of the philosophy that is used in design codes of practice around the world in which it is acknowledged that there is a finite but real probability that a combination of overload and under-capacity can lead to the collapse of the structure. This is also seen in the philosophies adopted for motor vehicle design whereby the community accepts that the cost of providing protection for occupants against all possible accidents is unacceptably high and efforts are instead directed towards preventing accidents in the first place.

If it is assumed that 50,000 people occupied the towers and that 80% of the people below the levels of impact would manage to escape and 40% from the level above, about 17,000 people may have been expected to have perished. On this basis, although no less tragic, the fact that the deaths appear to have been limited to less than 7,000 souls could be seen as some form of testimony to the basic robustness of these buildings under these extreme loadings.