What Does and Does Not Explain the 9/11 Collapse of WTC Towers

Even after a decade of discussion and evaluation by many individuals and groups, there remains considerable misunderstanding and confusion regarding the underlying reasons for the collapse of the WTC towers. A completely rational and mathematically supported explanations for all of the events that have been observed, as well as a refutation of all of the erroneous theories that have been proposed, can be obtained by clicking the papers 405, 466, 476, 499, 578, 585, (and in Czech also 567), and also the discussions D20, D25, D27, D28. These and other relevant papers are gathered on the website: http://www.civil.northwestern.edu/people/bazant/PDFs/Papers.

The credibility of these explanations is supported by the fact that (a) they are based on universally accepted principles of structural mechanics, structural dynamics, and continuum mechanics, (b) they are widely accepted in the Engineering Mechanics Institute (EMI) and the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE), in the Applied Mechanics Division (AMD) of the American Society of Mechanical Engineers (ASME), in the American Institute of Steel Construction (AISC), in the Society of Engineering Science (SES), and in the International Union of Theoretical and Applied Mechanics (IUTAM), with no objections from any of these organizations, and (c) they do not disagree in any respect with the detailed analysis of the fire and collapse of the floors impacted by aircraft, carried out at the National Institute of Standards and Technology (NIST) under the direction of Dr. Shyam Sunder (cited in 476.pdf).

Paper 405.pdf shows clearly that the aircraft impacts alone were sufficient to cause complete collapse, driven only by gravity, and that the collapse progression had to be essentially vertical.

Paper 466.pdf derives the differential equations governing the vertical collapse mode with mass accretion, concrete slabs comminution, plastic energy dissipation in steel, dynamic air expulsion, and dynamic fragment ejection.

Paper 476.pdf refutes all of the main arguments by the laymen who believe in some sort conspiracy (including the arguments concerning high temperatures).

Paper 499.pdf and the four discussions refute the additional critiques and misconceptions stated by laymen after the publication of 476.pdf.

Moreover, paper 578.pdf summarizes the previous WTC studies (and 569,pdf gives a different summary in Czech). Also note that 578.pdf discusses the implications of recent column buckling tests at McMaster University.

Brief Comments on Questions Raised:

The aforementioned collapse analysis has been challenged by various intuitive, non-mathematical, interpretations of some later observations. Typically, after some input parameter was later found to differ from value assumed in the original calculations, the entire original analysis was claimed to be false. However, proper mathematical calculations based on the theories of structural dynamics, stability, plasticity and fracture have never been presented to support these claims.

In fact, the aforementioned papers indicated some big margins for the validity of the conclusions. For example, the kinetic energy of the upper part of tower gained upon falling through the height of the floor on fire was shown to exceed the dissipation capacity of the columns of the underlying floor by an order of magnitude. So if the bending moment in the plastic hinge at column mid-height appeared to be 3x higher, as found in Korol et al.'s reduced scale tests on aluminum columns, the energy dissipated by columns was still insufficient by far for stopping the collapse. This insufficiency was probably greatly increased by flexibility of column-beam joints and by fractures of steel (documented by photos of flying fragments), both of which were not considered in the original analysis, to obtain conservative estimates.

As another example, the column resistance must have, of course, reduced the velocity and kinetic energy of the top part upon hitting the first floor. But by how much? A serious analysis would have to take into account that the columns were damaged, many of them totally severed, all of them weakened by heating in fire, and overloaded on one side of tower due to eccentricity of aircraft impact and to tilting of the top part. Note also that, after the crushing front progressed through several floors, the resistance of columns shown by calculations became negligible compared to the energy needed to accelerate the accreting mass of the impacted floors at the crushing front (which the opposite of acceleration of a rocket by gas exhaust).

Furthermore, the loud booms that were heard, and the ejection of fragments and dust far to the side, are no surprise. In the lower stories, the air had to be ejected from each floor within 0.07 second, which implies a near-sonic (Mach 1) velocity of lateral air flow. The comminution of concrete floor slabs and other material to powder particles as small as 0.1 mm is also no surprise, since calculations based on Schuhman's law for rock blasting and on the impact energy on the concrete floors predict exactly that. Besides, note that, despite simplifications in various secondary aspects, the calculations gave a close match of the seismically recorded duration of collapse, as well as the motion history of the tower top, as documented by the first few seconds of the video record.

Finally, would Newton's principle of action and reaction not require simultaneous crushing upward and downward? No, because the differential equations for crush-down and crush-up are different. In the former the accreting mass is getting accelerated, in the latter decelerated.

Conclusion: After the aircraft impact damage and fire, progressive collapse was inevitable. Gravity suffices to explain it. No observations have been proven to be in conflict with this conclusion.

For Slovak readers: 00-Slovak newspaper article.pdf and 00-Slovak article-expanded.pdf