Discussion of "Progressive Collapse of the World Trade Center: A Simple Analysis" by K.A. Seffen

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Seffen's paper presents what it calls a simple analysis for the dynamics of the World Trade Center (WTC, implicitly just the South and North Towers) collapses. He claims the "factors responsible for the onset of collapse are now well established", that:
(1) intense fires created by the aircraft compromised the remaining intact columns near the impact [those undamaged by the plane collision] to sustain the weight of the building above them.
(2) The subsequent "near free fall" of these upper parts over just 1 story resulted in dynamical overloading of the undamaged columns below by a "factor of over 30".
Seffen then goes on to develop a propagating instability model for how the fire brought the Towers down. But these claimed factors are factually inaccurate. Furthermore, in analyzing the model built on these factors, ideal assumptions are made that are in disagreement with physical principles inherent in the collapses of the Towers, and yield solutions that cannot provide answers or much insight into how the Towers fell.

While the theory of these factors responsible for the onset of collapse have been "well-proposed" as the cause of the collapse, they have **not** been well-established as factors that explain well the observations of the collapse. The theory that Seffen is improving on is the "crush-down, crush-up" theory proposed initially by Bazant and Zhou (2002). Yet this theory does not agree very well with observations on how the Towers fell. For example, as film documentation of the South Tower collapse shows, the top part of the South Tower does not even come close to "crushing up" after the bottom part of the Tower "crushes down" to the ground.(NBC films, 2001) In fact, the top part started toppling and fully disintegrated into gray clouds (produced from pulverizing concrete from areas on fire) in mid-air, **above** the lower part of the Tower (producing only white clouds from pulverizing concrete below where the fires were), and it did so *well before* the lower part came down. In addition, **both** of the Towers show major horizontal forces in their collapses, forces which are fully ignored in the "crush-down, crush-up" theory, which treats the downward gravitational force as the only force acting in 1D analyses of the collapses and neglects all horizontal motion. The factors responsible for the onset of collapse assumed in this "crush-down, crush-up" theory are clearly not well-established.

Furthermore, it has been "well-established" that the factors that caused the onset of collapse in the South Tower appear definitely to **not** have been the fires. The fires created from the plane impacts were not that intense just before the collapse initiation for either Tower, and for the South Tower the fires seemed close to being contained and put out by the firemen when suddenly rapidly horizontally-moving masses of material violently broke through walls of the floors **below** where the fires had been burning from the plane hit. As the film documentation shows, the collapse of the South Tower

initiated *1-2 stories below* the lowest floor where the fires had been burning, with very dynamic (roughly 40 mph) hurtling of white material (broken and pulverized concrete) in the horizontal direction away from the building — material with absolutely **no** fire associated with it.(NBC films, 2001) This ejection and a subsequent horizontal ejection of rapidly-moving white material at floors just near this formed the white clouds around the lower segment.

As presented by Grabbe (2008a), the force that ripped the South Tower apart at one edge in the collapse was a force an order of magnitude larger in strength than that of the force of gravity (the only force acting in Seffen's model for the collapse). There is similar evidence that the fires were not the cause of the North Tower collapse, such as the energy analysis in Hoffman (2003) that calculates the amount of energy expended in the collapse of the North Tower to be about an order of magnitude larger than the energy that is available for gravitation collapse, the sole force in the model of Seffen. These analyses effectively disprove what Seffen refers to as a "well-established" assumption – that gravitation was the only force involved in the collapses of the Towers.

Seffen builds on Bazant and Zhou's 2002 paper (hereinafter called BZ), referring to their work as establishing the virtually "free-falling" upper parts that initiated the collapse, even though BZ provided no physical mechanism that can possibly allow such free-fall. Seffen states that then the subsequent gravitational "near free-fall" of the upper parts over the height of just one story resulted in dynamical overloading of the undamaged lower columns by 30 times their static load. But there is no evidence to support this incredible inference that as a result of the claimed gravitational initiation the upper parts were suddenly virtually free-falling, nor are there means by which grav-

itational collapse can produce such a "near free-falling" state. For "near free-falling" to happen, the contiguous solid material making up the building below these sections where the collapse initiates would suddenly massively lose its cohesion, an action the fire **above** this solid material cannot possibly cause. That stationary momentum of that lower contiguous material counters the momentum of falling parts from above, and conservation of momentum keeps the free-fall state from being approached.

The only thing this author knows of that could create a virtual free-falling state is massive explosions well below the fires, which could effectively "liquefy" the lower structure. Direct evidence for explosions, which were created by forces other than gravity (such as the horizontal forces in the South Tower collapse initiation), was presented in Grabbe (2007). Those forces are, of course, not present in Seffen's model.

Seffen completely ignores conservation of momentum in all his uses of the word "free-fall". He has mathematically converted the problem from one of analyzing Newton's equations of motion to an instability analysis of the column as a whole, in order to improve on the the story-coupling limitations of the BZ analysis. However, one cannot ignore conservation of energy and momentum, and the implications of these conservation laws is that the free-fall cavalierly referred to *cannot happen* in the gravitational collapse of the Towers analyzed in Seffen's model.(Grabbe, 2008b) He effectively avoids the problems of the conservation laws in his analysis, but they not gone away, and prevent achievement of the virtual free fall he asserts.

Seffen correctly identifies one of the several inadequacies of the BZ analysis, saying "However, the link to progressive collapse is improperly asserted by claiming that, because each story locally collapses in an unstable manner, successive stories are bound to fail sequentially." In fact, there is no reason a gravitational collapse could not stop, at

least temporarily, upon hitting adequately-sturdy structure in the story below. Seffen tries to correct that inadequacy in BZ analysis by analyzing whether this is a propagating instability. However, like BZ, he uses a grossly inadequate 1D model of the Towers. The Towers **cannot** be analyzed as 1D sticks (i.e. 1500 ft "telephone poles"). This grossly ignores the horizontal extensions of the Towers, and completely misses the internal structure that would be a major resistance to such instabilities – indeed, also a major resistance to anything approaching free-fall. The Towers were well-constructed over 44,000 ft^2 horizontally for this stability, and all of that is ignored in the simple 1D model that Seffen analyzes.

Seffen states that "Each story is assumed to compress homogeneously such that the overall 'wake' above the crush-front and below the initiation site has a larger, uniform density." On the contrary, the early stages of the fall of the South Tower were *very non-uniform* over these other 2 dimensions, making this 1D model fully inaccurate. Using this oversimplied 1D model of the Towers, Seffen calculates the conditions for the instability in Eq (21) as the maximum value the variable he defines as p^* (non-dimensionalized variable proportional to what he calls the "steady-state propagation pressure" P^*) can be to still "assure collapse" of the building. Furthermore, if p^* is sufficiently smaller than unity in his model it can apparently achieve the speedy collapse observed for the Towers. Clearly his determination of what p^* is for the Towers is no good because of invalid assumptions used, including in particular the major oversimplifications from his 1D model.

His statement on that "More realistically, if there is a column fracture, p^* is much less than unity" shows this 1D assumption is clearly wrong because it ignores important aspects of the 3D behavior of the Towers. There are actually about 286 columns,

and they are designed to deal with fractures in individual columns by redistributing the load to unfractured columns. Yet a 1D model must assume it is only 1 column. One could try to translate his 1D analysis into the assumed uniform behavior of all 286 columns, but in fact these 286 columns are engineered **not** to act uniformly? Furthermore, Seffen models the columns as being damaged by fire, but fire damage itself definitely cannot be uniform over these other 2 dimensions. There is no sensible way to make this translation, and the model is grossly unrealistic for the real WTC Towers.

Seffen ends the calculation correctly pointing out some of the limits of his model. Stating "Many simplifications have been made in this analysis for the sake of transparency," he mention some of these simplifications. However, he fails to describe one of the most crucial oversimplifications of his model: the analysis of the Towers as 1D objects. Such a treatment grossly oversimplified the very inhomogeneous nature of fire throughout the 286 columns spread over 44,000 ft^2 in those 3D Towers, leading to erroneous conclusions. One cannot correctly analyze the stability of a complex 3D structure in a simplified 1D analysis. Horizontal forces, complex building structure over the other 2 dimensions, and inhomogeneities of the forces of destruction over these 2 dimensions are essential considerations in any correct analysis.

On the positive side, Seffen's analysis of the 1D model might be viewed as a useful initial analysis for building collapses from fire that to lowest order fit the model he uses, possibly helping to identify important questions that need to be addressed in a more complex 3D followup (e.g. why has no other high-rise in any industrial nation **ever** collapsed from fire?). However, when this model and its analysis are applied as an effort to explain the WTC collapses, claiming this is what caused the collapses, it is decidely wrong, offering little in answers or insight how the WTC buildings fell.

His 1D model and analysis is inadequate because it ignores fundamental 3D aspects of the stability of the Towers, it disagrees with known physical principles such as the conservation of energy, momentum, and mass – conservation laws that show that the collapsing WTC Towers could *not* reach the virtual free-fall states observed by the gravitational force as claimed, and it substantially disagrees with several observations of how the Towers collapsed.

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