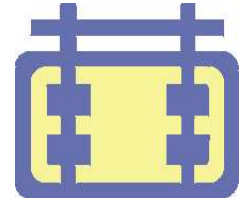


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Non-animated Visualization Aids to Assist in Understanding the Demolitions of the World Trade Center Twin Towers - Part 1



This article describes the structure of the **World Trade Center Twin Towers** and what happens when **the release of potential energy**, due to downward movement of the mass above one of its supporting columns when buckling, **exceeds the strain energy** that can be absorbed by the same column below. The conclusion is that no global collapse of the Towers can ensue under the given circumstances. The web page is intended for children and amateurs of skyscraper design who want to get a better understanding of the world around us. The **writer** is a structural engineer for **Heiwa Co** albeit in the shipbuilding and very big oil tankers sectors but the principles of structural design and analysis are the same.

0. The false theory and the misleading assumptions

An American professor Z P Bazant published soon after the WTC collapses 911 a **theory** that was adopted by the authorities as true. The Bazant analysis is that *if* prolonged heating caused the majority of columns of a single floor to lose their load carrying capacity, the whole tower is doomed. Bazant suggests there are five stages until the doom! I quote from his paper.

Stage 1: *The conflagration, caused by the aircraft fuel spilled into the structure, causes the steel of the columns to be exposed to sustained temperatures **apparently exceeding 800° C**. The heating is probably accelerated by a loss of the protective thermal insulation of steel during the initial blast.*

Evidently it was not possible that all 47 core and 236 wall columns in the initiation area - one floor 4 000 m² large - sustained temperatures **exceeding 800° C**! Later examinations show that only a few parts may have been heated max 500° C temporarily and locally. So the assumption about apparent temperatures exceeding 800° C is misleading.

Stage 2: *At such temperatures, structural steel suffers a decrease of yield strength and exhibits significant viscoplastic deformation i.e., creep - an increase of deformation under sustained load! This leads to creep buckling of columns which consequently **lose their load carrying capacity!***

It is correct that heat affects steel material properties as shown in [5.](#) below but if it contributed to the collapse is not ascertained. No column from the initiation area that had **lost its load carrying capacity** was found in the rubble. The local temperatures were later established to temporarily and locally have been max 500° C and the loss of load carrying capacity is then not critical. So the assumption about loss of load carrying capacity is also misleading.

Stage 3: *Once more than half of the columns in the critical floor that is heated most suffer buckling, **the weight of the upper part of the structure above this floor can no longer be supported**, and so the upper part starts falling down onto the lower part below the critical floor, **gathering speed** until it **impacts** the lower part. At that moment, the upper part has acquired an **enormous kinetic energy** and a **significant downward velocity**.*

As shown in [3.2](#) below the static compressive stresses in the supporting structure below was less than 0.3 x yield. If you remove uniformly half the supports evidently the supporting structure below will be stressed to 0.6 yield. So the assumption about the weight above not being supported by half of the columns is also misleading. And no buckling of any kind will occur at 0.6 yield stress compression!

Evidently more than half of the columns were never heated at all to any critical level as seen on videos. The outer walls were only locally and temporarily affected by fire. Nevertheless, assuming that more than half of the columns are simultaneously affected by heat, do these columns actually bend, twist or crumple up? Why do they not only compress more, while transferring the load to adjacent columns that still have ability to carry it? Why would the part (mass) above the heat affected column actually **gather speed**? The column parts are still connected. Why would the upper part and its mass **impact** the lower part?

What is the kinetic energy of the mass above? Why is it **enormous kinetic energy**? In [5.3](#) below it is shown that the energy could not have exceed 340 kWh in WTC1 which corresponds to abt 40 kgs of diesel oil! It is not an enormous amount of energy. So the assumption about enormous kinetic energy is also misleading.

And what is the **significant downward velocity**? In [5.4](#) below it is shown to be about 3 m/s or 10 km/h which is a very low speed that would not kill anybody in a car collision. So the assumption about significant downward velocity is also

misleading.

All videos - live forensic evidence - of the collapse however show that the upper part above the initiation zone actually disintegrates within 3,5 seconds after the roof starts to fall, so there is no rigid mass above to act on the structure below after that. The debris of the upper part is actually thrown outwards between **intact** wall columns at the initiation zone and produces a smoke and dust screen that hides the destruction of the lower part that starts after 5 or 6 seconds. The impact is indeed very strange

Stage 4: *The vertical impact of the mass of the upper part onto the lower part applies enormous vertical dynamic load on the underlying structure, far exceeding its load capacity, even though it is not heated.*

This event is not proven at all. Does really the **mass of the upper part** with 200+ deformed columns at its bottom acting as a damping device vertically impacts on the lower part? There is no evidence for that as outlined in [5.6](#) below. What is the **enormous vertical dynamic load** of the upper part? What is the **load capacity** of the underlying, not heated part? It will be shown in [7.](#) below that if the underlying structure is regarded as a spring, it will only compress max 78 centimeters due to an instantaneous vertical impact! And then bounce back! This is logical! The impact speed is low and the kinetic energy compressing the structure is very low and the structure below behaves elastically. So the assumptions about **enormous vertical dynamic load** and the deficient load capacity of the underlying structure are also misleading.

Stage 5: *This causes failure of an underlying multifloor segment of the tower, in which the failure of the connections of the floor-carrying trusses to the columns is either accompanied or quickly followed by buckling of the core columns and overall buckling of the framed tube (i.e. the wall columns), with the buckles probably spanning the height of many floors, and the upper part possibly getting wedged inside an emptied lower part of the framed tube! The buckling is initially plastic but quickly leads to fracture in the plastic hinges.*

It is not clear why the alleged impact - an upper part with deformed columns below hitting a lower part with intact floors and columns - would cause the underlying floors to disconnect from the underlying columns? The floors are bolted to the columns. How can a column that has deformed previously above then deform a column below ... over the height of many floors? Why do not the columns above simply punch a hole in the floors and get entangled with the columns below and their spandrels? Stage 5 is very strange and not recorded on any video. So the assumption about failure of an underlying multifloor segment is not obvious.

Stage 6: *The part of building lying beneath is then impacted again by an even larger mass falling with a greater velocity and the series of impacts and failures then proceeds all the way down.*

Are actually any further impacts seen on any videos of the videos?

It will be shown in this article that most assumptions and conclusions in stages 1-5 are not correct and that the Bazant stage 6 is not possible.

1. Introduction - a bird cage

The structural design of the **World Trade Center Twin Towers** is very simple as its very lightweight steel framework is similar to a box shaped bird cage in which human beings are working. Most skyscrapers or office towers in the world are built according similar principles. None has ever globally collapsed in seconds before or after 911 except WTC 1, 2 and 7.

1.1 The bird cage wall bars and their spandrels

The vertical bars of the cage walls correspond to the outer wall steel columns of the Towers and are continuous from bottom to top (albeit 3 wall columns become one at the bottom of the Towers). The cage wall vertical bars are horizontally interconnected at regular levels by spandrels (a word that I cannot find in my **Advanced Learner's Dictionary of Current English** but probably has Latin origin - spandrilla? - used to support the ceiling of, e.g. the Sistine chapel at the Vatican) that are simple steel brackets. The spandrels act as belts around the bird cage that can prevent transverse (outward/inward) deflections of the wall bars. The spandrels will then be in tension/compression. On top of the cage is a roof. Inside the cage are floors fitted bolted to the walls. These floors also prevent transverse deflections.

1.2 The floors

To better use the volume of the cage 110 off floors were installed in it at regular intervals. The WTC floors were also very simple. A floors consists of about 4 inch of concrete poured on a thin plate of steel supported by lightweight trusses (beams) bolted to the columns, as you cannot glue concrete floors to the cage walls and core. Thus every wall column also carried a portion of the load of the floors.

The floors can only carry its weight + furniture, decorations and human beings on the floor. If a floor is overloaded for any reason, it will sag and the concrete will fracture in small pieces and the bolted connections to the columns will shear off. A dislocated column will simply only punch a hole in a floor.

1.3 The core columns

47 off box or I-shaped columns were installed inside the cage at its core - core columns to which the floor trusses were also bolted. The core columns reduce the span of the floor trusses,

A core column is similar to a wall column with dimensions tapered from bottom to top like a flag pole. It only carries its own weight + the load on the floors connected to it. The core columns are interconnected with spandrel like beams at regular

intervals. Evidently you fit elevator shafts, vertical cable/pipe/ventilation trunks and stairwells adjacent to the core columns.

1.5 The cage mass - volume wise most air

It should be clear that 94-96% of the volume of the bird cage consists of air and that 100% of the cage mass/load is carried in the vertical columns down to ground.

A column only carries its own weight + the load on the floors connected to it and the roof. At the bottom or ground level the columns thus carry the whole load of the column above and are tapered to smaller dimensions at the top only to carry the roof.

The compressive stress due to weight (mass) of a column is therefore uniform from bottom to top and well below any critical stress (yield or buckling) that is shown below.

1.6 Redundancy

The cage has very large redundancy, i.e. surplus strength due to the spandrels. You can remove a big number of columns or floors at any location (e.g. a plane or other object crashes into the cage or a small bomb goes off and makes a hole in the cage!) and nothing happens, as the compressive load in the removed columns is transmitted via the spandrels to adjacent intact columns and down to the ground.

1.7 Total mass of the Tower

Information about the total mass of the Tower differs from 250 000 to 500 000 tons but is of little importance. The Towers were sturdy and had survived many storms, etc. even if they then were subject to transverse deflections of several meters at the top. No defects were reported for 30+ years. The Towers also survived the initial impacts of planes on 911 due to their redundancy. When the Towers collapsed there were no storm wind forces acting on them.

1.8 Simplifications

In order to study the collapse of the Tower cage structure it is easiest and most educational just to look at one of the wall columns and one of the core columns of the cage. The compressive load in these columns is the sum of the load from the bolted floor truss connection at every floor and the weight of the column itself above.

2. Collapse scenario and cause of collapse - buckled columns

From NIST report - NISTNCSTAR1-6D chapter 5.2 - we learn:

*"The aircraft impacted the north wall of WTC 1 at 8:46 a.m. ... between Floor 93 and Floor 98. ... The subsequent fires weakened structural subsystems, including the core columns, floors and exterior walls. The core displaced downward ... At 100 min (at 10:28:18), the north, east, and west walls at Floor 98 carried 7 percent, 35 percent and 30 percent more gravity load loads ... and the south wall and the core carried about 7 percent and 20 percent less loads, respectively., ... At 10.28 a.m., 102 min after the aircraft impact, WTC1 began to collapse. ... The release of potential energy due to downward movement of the building mass above the **buckled** columns exceeded the strain energy that could be absorbed by the structure. Global collapse ensued."*

From chapter 5.3 we learn:

*"The aircraft ... impacted the south wall of WTC 2 at 9.03 a.m. ... between Floor 78 and Floor 84. ... (9:59 am) ... The release of potential energy due to downward movement of the building mass above the **buckled** columns exceeded the strain energy that could be absorbed by the structure. Global collapse ensued."*

Note that the two Towers collapsed for exactly the same cause: *The **release of potential energy due to downward movement of the building mass above the buckled columns exceeded the strain energy that could be absorbed by the structure.***

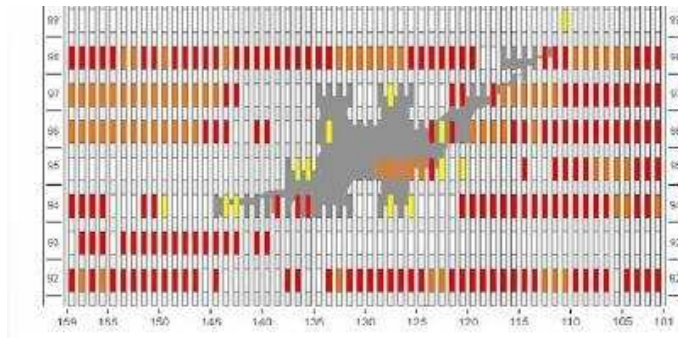
"Buckled" of steel structure by definition means bent, twisted or crumpled up and is the key word of the NIST announced only cause/effect of the global collapse.

Evidently a bent column does not result in much downward movement unless it is bent 180° and then removed! A twisted column does not result in any downward movement at all. A crumpled up column, i.e. compressed into folds or creases, produces downward movement but stops when compression stops.

It is sad that NIST cannot produce any **"buckled"** column of the initiation zones, be it bent 180° or crumpled up, that would have produced downward motion. We are talking about 566 columns that must have **"buckled"** for the effect ... and none is presented as evidence that potential energy was released for that cause.

No complete building or steel structure has ever globally collapsed in millions of pieces before or after 911! Evidently steel structures may collapse and deform but it is always locally and stops when the energy is absorbed or diverted elsewhere. This paper is mainly about WTC1 and it is necessary to have an idea of the initial damage to its North wall and its 59 wall columns, allegedly due to an airplane banking at 20° flying into it, as follows (from Ms [T Mc Allister, NIST, 15 Sept. 2005](#)):

North Face



As can be seen only about 38 of the wall columns were cut (65%) over 4 or 5 floors and the wall did not buckle or collapse. The loads in the cut columns were simply transmitted to intact adjacent wall columns via the spandrels and then to the East and West walls and the core. This was not a serious damage. No potential energy was released at this time. Some people even doubt the hole was caused by a Boeing 767! It looks too small and the vertical extent would indicate that the plane was travelling with one wing much higher than the other, etc. This writer thinks the hole is too large! The aluminium wing tips would never cut through the steel wall columns but would be ejected, bouncing backwards! It is a pity no broken parts of the North wall were recovered in the rubble. They should have been on the top of the rubble.

It may be interesting to know how the vertical subsystems, i.e. the walls and core columns carried the gravity load in WTC1 before (60/40 walls/core) and after hole was made in the North wall and after 100 minutes of fire in below table:

Subsystem	Original load distribution (%)	Load distribution after hole made in North wall (%) (estimated)	Load distribution change due to 100 minutes of fire according NIST	Load distribution after 100 minutes just before global collapse (%)
North wall	15	7	+7%	7
East wall	15	17	+35%	23
West wall	15	17	+30%	22
South wall	15	15	-7%	14
Core	40	44	-20%	34
Total	100	100	0	100

As can be seen from above table, just before global collapse only the East and West walls carried more gravity load than original. In [3.2](#) below it will be shown that this extra load would not overload the columns in these walls.

2.1 The buckled columns

It is suggested in NIST report - NISTNCSTAR1-6D that all the wall and core columns buckled simultaneously in the impact area as they were affected by fire/heat 40-100 minutes later that reduced their strength (yield stress) and caused subsequent overloading.

Even if this phenomenon is not seen on any video of the collapse itself - *instant forensic analysis* - or in the columns of the rubble afterward - *post mortem forensic analysis* -, let's assume that our vertical cage bars or columns buckled due to heat of the fire.

Buckling of the cage bar or column occurs, when the compressive stress in the bar exceeds the critical buckling or collapse stress of the bar. The critical buckling stress is only a function of the slenderness ratio of the bar, its cross area and material properties. Only the material properties are affected by the heat but are virtually unchanged between 20 and 500° C but let's assume that, e.g. the yield stress is reduced by 20% (from say 248 to 200 MPa) at 500°C. The wall bar is obviously fitted in the wall and cooled by external air and can never be heated very much. That is why the wall perimeter steel columns were not fire proofed but only fitted with normal heat insulation against sun and winter weather below an external aluminium cladding.

When the wall bar buckles, it will deflect sideways which however is prevented by both the spandrels and the floors, i.e. it can only buckle between these supports. Both spandrels and floors keep our wall bar in vertical position as long as they are intact. If the floor bolted connections are sheared off and the unsupported length of the bar between floors increases, the spandrels will still restrain outward or inward deflection of our bar due to buckling. Same applies to a core column.

2.2 Release of potential energy due to downward movement

Downward movement of the mass above, i.e. the columns' weight and the load of the floors attached to them are only possible due to transverse deflection of the columns.

If the column does not deflect, there is no downward movement of the mass above and thus no release of potential energy.

3. Arrangements at floors 94-98 of WTC 1

Let's look at WTC1 and floors 94-98 - the initiation zone. Total area of each floor is about 4 000 m².

A wall bar or column there is a box with side 300 mm and wall thickness, say 12.5 mm. The cross area of the steel is thus about 150 cm². The bar weighs about 120 kgs/m incl. spandrels, i.e. is quite light. There are about 236 wall columns. Total cross area of all wall columns is then 3.54 m²

Let's assume that the total mass of the wall steel columns above floors 94-98 is about 1 500 tons.

The highest loaded core columns are the outer ones, e.g. number 501. It is an H-beam with two flanges 17x3.5 inch connected by a 2.2x12.6 inch web. In metric terms the cross area is about 950 cm², i.e. the bar is very solid. It weighs 750 kgs/m.

There are 47 core columns most of them with less cross area than the outer ones. Let's assume that total cross area of all core columns is only 2.1 m², i.e. 60% of the wall columns. Then the total mass of the core columns and spandrels above floors 94-98 is about 900 tons. The core is thus lighter than the perimeter wall.

A floor including furniture, etc is assumed to weigh about 1 850 tons. The total mass of floors and the roof above floors 94-98 is about 26 000 tons. Most of this weight is in fact concrete poured on a thin corrugated steel plate supported by trusses that in turn are bolted to the columns. There are about 700 connecting bolts per floor. Let's summarize the total mass above as follows:

3.1 Total mass above floors 94-98 - 33 000 tons

Steel wall columns	1 500 tons
Steel core columns	0 900 tons
Steel floor trusses	3 000 tons
Concrete floors	23 000 tons
Windows and misc.	4 600 tons
Total	33 000 tons

Note that less than 10% of the mass is steel in the supporting columns and that as much as 70% is concrete. If this mass filled the total volume of the building above the initiation zone (190 000 m³), the uniform density would be 0.18 ton/m³ or the density of cotton! **You could say that a big bale of cotton (mass above) rested on the structure below!**

This mass is carried about 60/40 by walls and core.

A floor can only transmit its own weight and load on top of to the nearest column. A floor cannot transmit any major load from a core column to a wall column and vice versa - the bolts will then shear off or the trusses will tear apart. The concrete just cracks! Wind loads on one wall may be transferred by the floors to the opposite wall as horizontal loads.

End of Part 1

[Go to Part 2](#) it is more interesting than Part 1 with videos that clearly show what happens before downward motion starts, etc.

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