NIST AND DR. BAZANT
- A SIMULTANEOUS FAILURE

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INTRODUCTION

The NIST enquiry into the destruction of the WTC towers purported to be an examination of the physical evidence. The final report includes commentary upon much of the physical evidence available from this examination but concentrates upon the time period prior to the onset of the collapse. The report does not go into much detail of the period of the collapse itself but instead relies upon the theoretical work of Dr. Bazant, to argue that once collapse was initiated then total collapse was inevitable.

Dr. Bazant attempts to explain the balance of energies at a point in time immediately after collapse initiation. He states that,
" *To arrest the fall, the kinetic energy of the upper part, which is equal to the potential energy release for a fall through the height of at least two floors, would have to be absorbed by the plastic hinge rotations of one buckle, i.e., Wg/Wp would have to be less than 1. Rather, Wg /Wp ?= 8.4 (3) if the energy dissipated by the columns of the critical heated floor is neglected*."

In other words, the energy available to progress the collapse was 8.4 times greater than the energy required to progress the collapse.

FLAWED ANALYSIS

However this work is fundamentally flawed in two key areas. Examination of these errors, either separately or together, reverses the conclusions reached by Dr. Bazant that the collapse would continue to progress to ground level.

Dr. Bazant argues that all of the potential energy associated with the fall of the upper section of the tower through two storey heights [the storey where the failure occurred and the uppermost storey in the lower section] would be concentrated into the destruction of the uppermost storey of the lower section. This energy would overwhelm the ability of the columns of the uppermost storey to absorb energy and collapse would progress through this storey. The available energy would then be concentrated into the next storey down and the tower would collapse one storey at a time to ground level.

The first error which Dr. Bazant has made is his assumption that all of the available energy would be utilised exclusively in the destruction of the uppermost storey of the lower section. **This is physically impossible under any and all circumstances.**

The energy available to the collapse is derived from the mass of the upper section. This mass is distributed throughout the upper section. Take for example the mass of the topmost floor slab of the tower. How is it possible for this mass to have its effect upon the uppermost storey of the lower section? In order for the energy associated with this mass to act at the collapse front it must be transmitted through the columns of the upper section. This energy has no other route to the collapse front other than through these columns. The very fact that all of these upper section columns are subject to load, means that they would absorb energy, in the form of elastic and plastic strain. Thus Dr. Bazant's argument that all of the energy would be concentrated into overcoming the columns on the uppermost storey of the lower section cannot be true.

It is impossible for all of the energy of the falling section to act on only the one topmost storey in the lower section, since the very act of transmission of the energy to that storey, dictates that all of the storeys in the upper section will come under load and consume energy

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Consider the time period immediately after the collision between the upper and lower sections. To illustrate and assuming the upper mass velocity at a constant 8.5 metres per second after full gravitational acceleration over 3.7m, then the time taken for the upper section's columns to be loaded even to their elastic limit would be at least 15 milliseconds. During this time period the individual masses within the upper section would in actuality be decelerating and applying increasing loads. The lower section would respond in a converse manner, with masses accelerating as they come under the influence of the forces acting outwards from the collapse front. There is nothing to suggest that this reaction would be confined to only the topmost 3.7m of the lower section's columns. During the time period when the energy is gradually applied to the collapse front through the available routes it will also dissipate from the collapse front, through the available routes.

Nor is this deformation of the columns in the upper and lower sections limited to their elastic range. **It must be noted that the columns in the upper section could not deliver a greater force than they themselves were able to transmit.** In a situation where the columns in the upper section were asked to deliver loads at magnitudes sufficient to cause plastic deformation of columns in the lower section, then they themselves would simultaneously suffer plastic deformation at levels proportionate to their ability and applied loads.

The columns of the upper section were manufactured from lighter material commensurate with their design requirements and the ability of these columns would likely be more affected by aircraft impact and subsequent fires, than columns at lower levels. This factor

would suggest that deflections and thus energy demands are likely to occur preferentially in the upper section.

Thus we can see that, in reality, the energy of the falling upper section of the tower would not be utilised to crush only one storey of the tower, but would in fact be distributed throughout the upper section as well as storeys in the lower section. Energy would be absorbed over many more storeys than the first impacted storey of the lower section.

This is both obvious and intuitive. In a collision, energy is dissipated in both the impacting and impacted objects in proportion to their relative strengths, characteristics and construction. To give an easily visualised analogy, imagine a large truck parked with its rear end against a solid wall and a car accelerated headlong into the front of the truck. Many things may happen, but one possibility which can easily be ruled out is that the car will pass all of the way through the truck, suffering no damage as it totally destroys the truck, until such time as it strikes the wall, at which point it is itself destroyed. This scenario is precisely what Dr. Bazant would have us believe with his "crush down - crush up" theory.

FACTOR OF SAFETY

The second error made by Dr. Bazant is his failure to take account of the factor of safety designed into the towers' construction. He makes no mention whatsoever of this crucial design parameter. This failure leads to a major underestimation of the ability of the columns to resist the downward acting forces.

The effect of this error by Dr. Bazant is an error in his ratio of energies. If this is adjusted to take account of a factor of safety of 4 the ratio is reduced from his value of 8.4 to 2.1. It must also be noted that the ratio mentioned by Dr. Bazant is relevant only to the first collision after a freefall of one storey. He is specifically dealing with a situation where the energy of the fall through two storeys is resisted by the columns of one storey. The continuation of the collapse would not have these conditions but rather have the fall of one storey resisted by the columns of one storey. Without the period of uncontested freefall the ratio of energies would be reduced for the remaining duration of the collapse from Dr. Bazant's figure of 8.4 to 1.05.

Since Dr. Bazant has stated that his figure of 8.4 corresponds with the observed collapse times of the towers, we can easily reverse this logic to say that if 8.4 corresponds to the collapse times which were present, then 2.1 certainly does not. Indeed examination of a simple series of calculations such as Dr. Bazant mentions shows a theoretical, total collapse time of about 11 seconds, but adjustment of the ratio to give due consideration to the safety factor increases the theoretical collapse time to about three times this figure, about 35 seconds. Thus even using his flawed analysis and assumptions, and making only one change to take account of the safety factor, it can be simply shown that the collapse times obtained by this analysis do not correspond to the collapse times which were observed in reality.

A more meaningful examination of the collapse would not rely on theoretical collapse times and total collapse times measured in such a difficult, dust shrouded situation, but rather have regard for the more obvious and more pertinent section of the collapse, the initial acceleration of the collapse front as it passes down the building. NIST did not avail themselves of the opportunity to make use of this important information.

Thus, a correction of this single error by Dr. Bazant, irrespective of any other consideration, shows that the observed collapse times were too short to have been caused by a gravity only collapse in the manner which he suggests.

FURTHER DEMANDS

Dr. Bazant has correctly stated that,
"*To arrest the fall,.....Wg/Wp* (the energy ratio) *would have to be less than 1*."
We have already shown that the figure of 8.4 given by Dr. Bazant can be markedly reduced and it would be possible to reduce the ratio still further by taking account of several other energy demands of the collapse such as;
Upon impact of the upper and lower sections, the columns would act to decelerate the floor slabs. The floor slabs' inertia would cause them to flex, with the maximum deflection being about their mid-span. This deflection dictates that energy would be consumed by this action.

The same action, the differential decelerations of the columns and floor slabs, would demand that further energy would be consumed in deformation, elastic or plastic, of the floor to column connections.

The initiation of the collapse would require some means to compromise the structural ability of the columns in question, and unless energy other than that available from the potential energy of the structure's mass was utilised to perform this task, the figure of 8.4, given by Dr. Bazant, should be adjusted to reflect this energy usage. Dr. Bazant does acknowledge this energy requirement and states that it would result in a lowering of the impact velocity upon collision, when compared with full gravitational acceleration, by about 6%. This corresponds to about a 12% reduction in the energy of the falling mass. This factor in and of itself, without regard for any other consideration would reduce the figure of 8.4 to 7.9.

Energy would be consumed in crushing the floor contents and floor trusses
Energy would be consumed in the observed pulverisation of the concrete in the floors.

Buckling of the columns on two adjacent, perpendicular walls requires that the direction of the buckles would also be perpendicular to each other. This cannot happen unless the spandrel plates at and about the corners were caused to fail. The same stipulation would also apply to the core columns' horizontal bracing. These tasks would also require energy which could not then be utilised to cause failure of the columns themselves.

All of these demands would serve to reduce the ratio of energies still further and make the progression of the collapse even less likely.

Other factors such as failure of the columns by column section splice failure or eccentricities in the columns would have effects on the energy balance. These factors would reduce the amount of energy which could be absorbed by the columns in the lower section. But these factors would preferentially manifest themselves in the weaker more heavily damaged columns of the upper section. They would certainly not be limited to the uppermost storey in the lower section. This would have the effect of inhibiting the supply of energy to the collapse front and the lower section.

The energy available could be increased by assuming that the initiation occurred such as to allow a greater input energy than that obtained from a drop through a single storey. Dr. Bazant states that,
"*If the first buckle spans over n floors (3 to 10 seems likely), this ratio is about n times larger.*"

This is a more likely scenario. The first buckle, that which initiates the collapse, is more likely to have occurred over more than one storey. But at least equally likely, the first resisting buckle in both the upper and lower storeys would also be over more than one storey. I say this because of two reasons. Firstly, if NIST is to be believed, initiation was caused by a horizontal force exerted by the floors upon the perimeter and core columns. The resisting buckles would not have this horizontal force. The minimum buckle length of the individual columns, even when viewed as discrete items without regard for the action of spandrel plates or corner geometry is greater than one storey. Furthermore, the resisting buckles in the lower section would occur in areas which were not as affected by the aircraft impact and subsequent fires, and the columns in these areas were of a greater cross section and strength. Thus we can see that Dr. Bazant's figure of 8.4 is the maximum ratio which could be expected under the constraints which he has imposed.

CONCLUSIONS

Dr. Bazant has stated in his analysis, that his energy ratio would be increased in the event of early failure of the column end connections. This is correct and examination of the debris pile with specific regard for the numbered and identifiable columns from the area in and around the aircraft impact area could have given more precise information from a physical rather than a theoretical source.

The short cut taken by NIST in relying upon this theoretical work, allowed them to avoid a continuation of their examination to include the physical evidence available from the collapse. Such a continuation would have shown many points of evidence which cannot be readily explained by a collapse whose initiation and progression was caused as a result of aircraft impact and subsequent fires. It does however allow the authors of the NIST

report to pass responsibility to Dr. Bazant for this, the most important part of the investigation.

A theory which can be so easily refuted is not an adequate foundation on which to rest the conclusions of a report on an event with such far reaching global consequences.

But since NIST relies upon the work of Dr. Bazant to justify their assertion that collapse, once initiated, would inevitably progress to ground level, this refutation of Dr. Bazant's work and theory also serves as a refutation of this most crucial part of the NIST report.

References

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