

**Meeting of the National Construction Safety Team Advisory Committee
December 18, 2007**

Minutes

Committee Members

Paul Fitzgerald, Chair
Robert Hanson
Charles Thornton
David Collins
Forman Williams
John Barsom (did not participate)

Welcome and Introduction

Mr. Fitzgerald called the meeting to order at 1:05 pm. Five members of the NCST Advisory Committee (Fitzgerald, Hanson, Thornton, Collins, and Williams) were present on the conference call, which constituted a quorum. Mr. Fitzgerald reminded the committee that the meeting was being held in open session and that it was being webcast for the general public. He also announced that three individuals had requested the opportunity to speak during the public comment session and that those individuals would call in at approximately 2:30 pm to address the Committee.

Shyam Sunder, Director, Building and Fire Research Laboratory, and WTC Lead Investigator

[http://wtc.nist.gov/media/NCSTAC_December18\(Sunder\).pdf](http://wtc.nist.gov/media/NCSTAC_December18(Sunder).pdf)

Dr. Sunder presented an overview on the progress of the implementation of the recommendations that resulted from the investigation of the World Trade Center. He noted that eight recommended changes to the International Building Code were accepted for inclusion in the supplement to the 2006 International Building Code. He referred to the NIST press release issued in June 2007 for details on the code changes that were accepted (available on the NIST WTC website, <http://wtc.nist.gov>). An additional 47 code change proposals have been submitted to the International Code Council for the 2007/2008 code cycle. Dr. Sunder also noted that other organizations are actively considering changes to standards, codes, and guidance that are responsive to the WTC Investigation recommendations. These are positive movements by the private sector to respond to the recommendations and improve the safety of high rise buildings in the United States.

Dr. Sunder also announced that NIST has released a supplemental list of answers to frequently asked questions. This list has been posted to the NIST WTC Investigation website (<http://wtc.nist.gov>).

Dr. Sunder provided the committee with a brief overview of the status of the investigation of WTC 7. The overview included a review of the working hypothesis. He stressed that the

working hypothesis is based on scientific/engineering judgment and simple analysis models, but has not yet been fully evaluated through rigorous analysis. The working collapse hypothesis has not changed since first reported in June 2004. NIST has developed additional detail on the initiating event sequence based on fire-induced failures resulting from normal building fires occurring in the tenant floors.

Dr. Sunder concluded his remarks with an update on the schedule for completing the investigation. He noted that the global analysis is anticipated to be completed by March and that NIST anticipates releasing the draft reports for public comment in July of 2008.

Following these remarks, the following questions were posed by Committee members and answered by Dr. Sunder.

Q: What do you mean by normal building fires?

A: These are fires in spaces where the combustibles are normal building contents, ventilation is the normal building ventilation, and there are no exceptional combustibles such as diesel fuel in day tanks or in large tanks at the base of the building. In the case of the towers, the jet fuel was unusual, but even there we talked about normal building fires since the jet fuel burned within a matter of a few minutes. What burned over the next hour to hour-and-a-half were normal fires where the combustibles were building contents plus the airplane contents.

Q: But they were ventilated fires?

A: In both cases the ventilation was probably somewhat limited. Typically, when flames extend out from windows, there is excess fuel looking for air with which to react.

Q: What will be the magnitude of the final report? Will there be a sizeable amount of documentation as with the towers?

A: In the case of the towers, the final reports totaled about 10,000 pages. In the case of WTC 7, we anticipate the final reports will total about 1000 pages or less. We anticipate releasing three reports, but this has not been finalized.

Therese McAllister, Project 6 Co-Leader

http://wtc.nist.gov/media/WTC7_Approach_Summary_18Dec07-Final.pdf

Dr. McAllister summarized the technical approach being followed in the investigation of WTC 7 and the status of the investigation since the last meeting of the NCST Advisory Committee in December 2006. Following her presentation, the following questions were posed by the Committee members and answered by members of the Investigation Team.

Q: If fires start in a building and there is no firefighting effort, is the building expected to come down? Or would it be expected that the building would remain standing after the fires have burned out?

A: Buildings are currently designed based upon E119 test results for building components and subassemblies. In the E119 test, components of a building are subjected to prescribed standard time-temperature exposure and a rating is assigned (e.g., 1 hour, 2 hour, etc.). If the walls, floors, and ceilings were intact before the fire and if doors are closed, the fire is presumed to be contained in the room of origin for some period of time that is roughly related to the fire ratings of these partitions. This would provide sufficient time for people to evacuate and for automatic sprinklers or manual firefighting efforts to control the fire. This containment would also limit the intensity and duration of the fire such that significant loss of strength of the fire-related structural components should not occur. The assumption is that the system as a whole will survive that exposure. The implicit assumption is that when there is a situation where the sprinklers do not function, there would be burnout of the building contents without collapse. It is not surprising that different buildings will react differently when exposed to normal building fires. Buildings designed more conservatively, such as those with more compartmentation, smaller floor spans, more massive structural elements, and greater redundancy in the structural system will perform better than a structure that has large, open floor plans with few compartments preventing the spread of the fire. The science has not evolved to the point of designing to meet the performance objective of burnout without collapse. This was a recommendation made in the final report on the Investigation of the Collapse of the WTC Towers. There was also a code change proposal to require providing for burnout without collapse that was submitted to the International Code Council (ICC) 2006/2007 code cycle but was not approved. Two proposals on burnout without collapse have been submitted for the 2007/2008 code cycle. If either of these proposals is approved, design for burnout without collapse would be built-in to all buildings, not on a case-by-case approach.

Q: The time that the fires will burn is influenced by the fuel loading, so it is not just a question of building design, but it is also a question of building contents. If the objective is to design a building for burnout without collapse, then there should also be some restrictions on the fuel loading that could be put into the building after it is constructed. Has thought been given to that?

A: Yes, decades of thought and research have been devoted to that issue. Fuel (combustible) loading by itself does not tell the whole story; the *rate* of heat release in a fire is the most important factor. This is recognized worldwide and is beginning to appear in regulations and fire codes. Since the technology exists to manufacture low flammability products, there is the potential for additional requirements on families of building contents.

C: So, for WTC 7, 4 lb/ft² is an assumption that is closest to the observations, but in fact there was considerable uncertainty as to what the fuel loading actually was on the various floors of the building.

A: Yes. Remember that this value of 4 lb/ft² is the mass consumed in the fire. The actual fuel loading would be higher if much of the combustible mass was contained in file cabinets. The 4 lb/ft² was the result of an estimate for the WTC towers, based on the combustible mass of typical workstations and other flammable products and the density of these on the tenant floors. An estimate for the tenant floors in WTC 7 reached was the same value. There is definitely a degree of uncertainty in using these values and applying them to all the fire floors in the

buildings. Our sensitivity analyses indicated that significantly higher fuel loading led to greater disagreement of the fire simulations with the photographic evidence.

C: That certainly is true; on the other hand, there could be residual burning.

A: Absolutely.

C: Not all buildings are expected to remain standing after burnout. The building codes allow for “frangible buildings”. That is why we limit the heights and areas of certain types of occupancies and structures -- so that there is not a catastrophe associated with those kinds of events and so that we can address the needs of the occupants within a reasonable amount of time should those structures eventually fail. Most of the codes today assume that there is going to be some measure of intervention for fire protection of a facility if it is going to remain viable. If that does not happen, then there is some evidence of structures that have had burnout scenarios but even some of those had intervention either by mechanical means or by fire department response. Structures are lost on a daily basis. Residences are a primary example of that kind of structure, and it is not likely that the codes will mandate that there should be a complete burnout of those kinds of buildings without failure of the structure.

Q: In your remarks, on page 9, you talk about Case A, B, and C temperatures to be completed for the 16 story analysis, and then in the next bullet you talk about temperature files for a 47-story model. Could you describe how the 16-story and 47-story models are interconnected?

A: Yes, there is a four-step sequence of computational simulation, each involving a different model. We recreated the fires using the Fire Dynamics Simulator (FDS) combined with our best information about the contents and layouts on each of those floors where significant fires were observed, which were floors 7, 8, 9, 11, 12, and 13. FDS generated moving fires that gave a good match to the observed progression of fire available from photos and videos on the east, west, and north faces. This provided our base analysis, Case A. Given that there are uncertainties in the exact amount of fuel and in the layouts, that there are gaps in the photographic evidence, and that something may have been happening farther inside the building that could not be seen from the exterior, we decided to bound this fire by increasing the rise in gas temperature by 10% (Case B) and decreasing the gas temperatures by 10% (Case C). These changes are within the possible variability of the fires.

In the second step, the Fire-Structure Interface (FSI) was used to superimpose these gas temperatures on the structural components for each of the three Cases.

In the third step, ANSYS is being used to determine possible initiating events based on the three fire cases. The ANSYS model is focused on identifying what local failures occurred within the structure. This model includes detailed renditions of the lower 16 floors (which encompass those floors that could have been heated by the fires) so that we can account for the thermal and structural response. Above sixteen stories, the weight of the rest of the structure is included. Nothing is ignored in terms of the forces on that structure.

In the fourth step, we take information from the ANSYS modeling as input to the LS_DYNA model, which simulates the full 47 stories of WTC 7. The initiating event is used as an initial condition. LS-DYNA is a dynamic analysis that keeps track of mass and impact, such as was done for the aircraft impact analysis for the WTC Towers. We give an initial condition and then let the analysis run and see if we can simulate what was observed with the vertical progression of failure and the horizontal progression of failure.

Q: Were the fires were initiated in WTC 7 when the North Tower came down?

A: This is described in the 59-slide presentation. It is highly likely that the fires were initiated when the North Tower collapsed, although there could have been other factors as well. When the North Tower came down there were large pieces of debris including structural components from the tower that fell on WTC 7. When the South Tower fell there was dust, and possibly that went into WTC 7. There was a fire alarm condition recorded but not heard because the fire alarm system was on test condition that morning as it had been every morning at about the same time. As most in the fire world know, many things can cause ignition, because there are so many electrical outlets in a building, and places where a short circuit or other kinds of things can happen to ignite a fire. It is not our objective to find out when the fires ignited but to follow the fires as they developed and progressed through the building. Perhaps the collapse of the North Tower initiated the fires in WTC 7, but there could be other factors as well.

Q: There was a previous mention of the day tanks and pressurized lines for diesel fuel in WTC 7. A 4 lb/ft² fuel load fire moved every 20 minutes; essentially it started and stopped every 20 minutes, so if you do not have fuel in WTC 7, how could fires burn for as long as they had and taken out this major structure that had good fireproofing?

A: The fires in the towers did not stop after 20 minutes. The fires moved from location to location, meaning that at any given location the combustibles needed about 20 minutes to be consumed. While the combustibles at a location were being consumed, the fire front would be progressing to adjacent combustibles. Also, recall that the 4 lb/ft² is the fuel load that is actually consumed. The total loading of furnishings could have been higher if there were substantial numbers of file cabinets, etc. Furthermore, the jet fuel led to widespread ignition of the combustibles, but the jet fuel was consumed quickly and was a minimal contributor to the sustained fires that weakened the structures in WTC 1 and WTC 2.

In the case of WTC 7, the estimated combusted fuel load was similar to the 4 lb/ft² estimated in the towers. The initial fires were small enough that most were not visible at the windows for several hours. Most likely, these early fires involved only a small number of workstations at a time. The early fires raised the air temperatures, preheating other clusters of cubicles and leading to the larger fires seen during the afternoon.

Once the fires had begun heating the air, the overall air temperatures on a floor continued to rise as new combustible material became involved. The local air temperatures began to fall when the local fuel supply was depleted and fresh air reached that area. The heating of the structure through its protective insulation was a result of both the high air temperatures that were reached and the duration of those high air temperatures, not just the duration of local burning.

Q: Why would these fires have burned for as long as they did? If beams sagged, buckled, and pulled they had to be exposed to the fire for more than 20 minutes.

A: The critical issue is the combination of temperatures to which the beams are exposed and the duration of that exposure. The FSI calculations showed that the floor assemblies were sensitive to these exposures, reaching 500 °C to 600 °C in some regions. While the metal decking had insulation on its lower surface, the concrete floor slabs had no fireproofing on their top surfaces. The floor beams were slender elements and had low thermal mass, and the thickness of the thermal insulation on the floor beams was less than that on the girders and columns. The sensitivity to heat was compounded by the very large spans. In the northeast section of the building there were 2000 ft² large span floor areas. Our analysis indicates fairly large magnitudes of sag in these areas.

C: It sounds like you are questioning the use of spray-on fireproofing for a 2 hour rating on a wide flange beam as effective fireproofing in the absence of sprinkler systems.

A: What we are beginning to find is that ratings of individual components may not be a sufficient indicator of the thermal response of the larger structure.

Q: I am not questioning what you are doing, I am questioning the way that American architects and structural engineers design buildings with spray-on fireproofing. I think you are basically coming out with a conclusion that maybe it does not work.

A: We will not make a recommendation at this point. Your input is very meaningful to us, and when all of the analysis is finished we will be in a position to make a statement about design practices.

Q: This question has to do with World Trade Center 4, 5, and 6. My understanding is that the portions that collapsed were the portions where the towers came down and the rest of the buildings experienced complete burnout with sagging of beams but not collapse. Is that true?

A: World Trade Center 5 had some interior failures which were noticed because the roof was intact above these failures. There was a section on the east side of the building where floor beams had failed at connections. There were tees sticking out from the columns and the connections were made several feet away from the columns. Those connections failed in a number of places. You are correct on WTC 4 and 6; the damage there was due to the towers falling on top of them.

C: I appreciate all the effort NIST has made, and based on the summaries we have heard I am quite pleased. On the other hand, there are some questions that will be coming up, and I look forward to reading the documentation that describes and supports what NIST has been doing over the last couple of years. It is going to be very important, and the conclusions that come out of it could have far reaching effects, so we have to be careful that we do not miss something of great import.

C: As structural engineers design longer and longer floor spans, we will need to pay attention to the fire ratings.

Q: The connections could have had a considerable impact on how this building performed. Can you explain what the connections were and how they were fireproofed?

A: There were two basic types of connections. One was a shear connection where the connection was between the web of the beam and the column, and the connection was made either with a single plate or double angles and then bolts and welds. How they used the bolts and welds either on the column or on the beam web identified three types of shear connections. The girders, which often supported the floor beams where they framed into the columns, had what we call a bearing seat connection, so there was a fairly substantial plate either constructed to look like an angle or supported off the column and that made a seat for the girder to sit on. Additionally, they had a clip, a lighter tie either at the web or at the top flange, mostly to provide lateral stability when the building was under construction rather than any real transfer of structural loads once the building was functioning. Of course there were variations on those connections, for example if the girders did not frame orthogonally into the face of the column, then we had to consider the angles. The particular geometries might have a change in sizing of different elements and that would change the mode of failure or the load at which failures might occur.

Q: What was the fireproofing on all those connections?

A: The drawings we received on the connections did not specify any information about fireproofing. What we have been using are photographs of the building when it was under construction and an understanding of standard practice for applying the fireproofing material that was used in WTC 7.

Q: Are you suggesting that there is no concrete information as to whether fireproofing was actually applied or not?

A: No, we have photographs that show the nature and extent of the fireproofing. However, in general practice the thickness of fireproofing applied to connections is not specified.

C: I suppose that the average engineer would assume that it is the same as the thickness on the beam or the column.

A: Yes, that is how it is done in the field. Prior to this investigation, we did not really know how connections behave in fire; in terms of the E119 testing that is done. Our recommendation in the towers report, which we will probably need to look at in the context of the WTC 7 report, is to develop an understanding of how connections perform in fires.

C: That is where I was going with this. You do have to address that issue.

Discussion of the NCST Advisory Committee Report to Congress

Mr. Fitzgerald prepared a draft letter report to Congress which was circulated to the Committee members prior to the meeting in order to frame the discussion. The letter format followed the format that was used for last year's report since there were no new investigations and little activity on the part of the Committee. The Committee members were in agreement on the format and the content of the draft report. Following discussion of a number of editorial changes, the Committee voted to accept the report to Congress with the editorial changes discussed. Mr. Fitzgerald took the action to make the editorial changes and prepare a final version of the report for transmittal to Congress.

Public Comment Period

Mr. Richard Gage

<http://wtc.nist.gov/media/AE911Truth-NIST-Written-Submission12-18-07.pdf>

http://wtc.nist.gov/media/AppendixC-fema403_apc.pdf

<http://wtc.nist.gov/media/JonesWTC911SciMethod.pdf>

Mr. James Gourley

Mr. Jerry Leaphart

<http://wtc.nist.gov/media/121807CommentNISTJerryLeaphart.pdf>