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Collection of Data on Fire and Collapse, Faculty of Architecture Building, Delft University of Technology

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Abstract: On May 13, 2008 a sizeable portion of the Faculty of Architecture Building at Delft University of Technology (TUD) collapsed following a fire. This is significant in that collapse of reinforced concrete buildings due to fire is rare. In order to facilitate analysis of this fire and collapse, the research team met with TUD personnel, fire fighters, eyewitnesses, and government researchers to collect data of scientific importance, including digital recordings of the event, structural plans, material specifications, architectural layout, data on building systems, information on contents, fire safety management procedures, and response of the occupants and fire fighters.

1. Overview: On the morning of May 13, 2008, a fire that started in a coffee vending machine on the 6th floor of the 13-story Faculty of Architecture Building quickly developed into an extreme loading event. Although all building occupants evacuated safely, the rapid fire spread severely impacted fire department operations, allowing the fire to burn uncontrolled for seven hours, eventually resulting in the structural collapse of a major portion of the building. The damage was significant enough that the building had to be demolished.

Collecting and archiving data from this fire is extremely important because structural collapse of high-rise buildings due to fire has historically been quite rare. There are several reasons for this, from the overall infrequency of fire ignition in high-rise buildings, to the combination of structural fire resistance of the frame, fire-rated compartment barriers, automatic fire suppression systems, and fire department suppression activities. This fire offers a unique opportunity to study the performance of a high-rise building in a major fire wherein one or more of these measures were absent or failed to provide the expected performance.

Fig. 1. Photograph of Faculty of Architecture building in 1970 [1].

Fig. 2. Photograph of Faculty of Architecture Building, TUD, following fire and partial collapse [2].

2. Data and Information Needs: In order to facilitate reconstruction and analysis of a fire event, it is necessary to gather sufficient data and information to (a) develop a time history of the incident, (b) determine the location of fire origin, and (c) establish factors contributing to the fire growth, including successes against the fire and critical failures contributing to its spread [3]. This data subsequently supports failure analysis, which focuses on building performance during the incident, given the building, occupant and fire characteristics. Successful fire reconstruction and analysis therefore requires obtaining pre-fire history and trans-fire information. The following summarizes the types of pre-fire and trans-fire data and information desired for this event [3, 4, 5].

Pre-Fire Data and Information: Pre-fire data and information establishes the condition of the building, training of the occupants, and emergency response procedures in place prior to the fire event, and includes:

1. Architectural, structural, mechanical, electrical, plumbing and fire protection features of building as built and at the time of fire.
   a. Building and fire codes, permits, certificates of occupancy / approval.
   b. Site plan(s) with buildings, roadways, ponds, etc.
   c. Design drawings and documentation (as constructed and any renovations).
      i. Architectural drawings and documentation, including detailed floor plans and elevations, interior and exterior wall details (materials, openings (location, size), opening protection (glazing, doors, etc)), interior finishes, glazing size, material specifications and location, door size, material specifications and locations, shaft locations (lift, stairs, mechanical, etc) and protection and rating (concrete, gypsum, glazing, doors, dampers, sealants, etc).
      ii. Structural drawings, calculations, material specifications, and test results, including for foundation, columns, beams, floor and ceiling assemblies, wall assemblies, roof structures, connections, materials, load calculations, fire protection.
      iii. Mechanical drawings, calculations, equipment specifications and commissioning reports, particularly forced-air ventilation (fans, ducts, dampers, etc, including capacities, locations and ratings, both horizontal and vertical), natural ventilation systems and components, smoke control systems or components, plumbing, including fire suppression (standpipes, hoses, sprinklers, etc).
      iv. Electrical drawings, calculations, equipment specifications and commissioning reports, including lighting (normal and emergency), circuits and capacities, breaker limits, power outlets, fire alarm and notification systems and components (types, locations, reporting, etc).
   d. Test, inspection and maintenance reports (detection and alarm systems, fire suppression systems (standpipes, hoses, extinguishers), emergency lighting, mechanical systems, etc.

2. Information on the building uses, contents, etc.
   a. Room by room description of room use, types and locations of contents, permanent or temporary displays (at time of fire).
      i. Photos of building interior and exterior.
   b. Room by room expected / typical occupant load / occupant characteristics.
   c. Any special hazards (fuel storage, chemicals, etc) and locations.

3. Facility and emergency management procedures and protocols, including:
   a. Operating hours / accessibility.
   b. Emergency plans (pre-fire plans, evacuation plans and drills, alarm reporting procedures, employee and student training, etc).
   c. Past history of events and outcomes (drills, fires, other emergencies).
   d. Detailed statements from building occupants to determine pre-fire conditions of building.

Trans-Fire Event Data and Information: Trans-fire events are those events from the point of established burning to extinguishment. Data regarding trans-fire events can be obtained from the following sources:

1. Still (photographs) and action recordings (digital movies, video, etc) at all stages of the fire.
   a. Photographs to be cataloged and documented on a diagram with description of what is being viewed, direction of view, location of photographer, etc.
   b. Video/digital images to be cataloged and documented with description of what is being viewed, direction of view, location of photographer, etc.

2. Interviews with first responders to determine their response, set up, actions on scene, including fire-fighting and rescue operations, including:
   a. Dispatch/run logs
   b. Occupant locations at time of fire until evacuated
   c. First responder initial positions / positions by time sequence
   d. Transcript of fire-ground communications
   e. Apparatus fire-ground positions
   f. Tactical approach

3. Interviews with building occupants.
   a. Location at time of fire and subsequent actions
   b. Estimates of fire location and size (for time line)
   c. Location and degree of fire damage observed
   d. Location and types of fuel materials observed

4. Maps / diagrams / general information.
   a. Information from the on-site fire protection systems (logs from panels, if available)
   b. Weather conditions

Collection of these types of data and information are consistent with other investigations of significant fire-related structural collapses, including those of World Trade Center towers 1, 2 and 7 [6, 7].

3. Data Collection: A critical aspect to this project was to establish relationships with local personnel who had access to data, information and personnel of interest. This was accomplished by establishing collaboration with Dr. IJsbrand van Straalen, a senior researcher in building design and regulatory issues at TNO (the Netherlands Organization for Applied Scientific Research, http://www.tno.nl/). Dr. van Straalen subsequently facilitated a relationship with Efectis (http://efectis.com/nl_en/index.htm), a daughter company of TNO, which agreed to collaborate with us in the collection of the fire data, and with Prof. Kees van Weeren, TUD Faculty of Architecture, whose office was in the Faculty of Architecture building, and who has been giving lectures about the fire at various venues.

An initial meeting was arranged in Delft to discuss the data collection effort in October 2008, involving:

- Brian Meacham, WPI
- Michael Engelhardt, UT
- Venkatesh Kodur, MSU
- IJsbrand van Straalen, TNO
- Johan Maljaars, TNO
- Kees van Weeren, TUD, Faculty of Architecture
- Kees Both, Efectis Netherlands
- Daniel Joyeux, Efectis France
- René de Feijter, Efectis Netherlands

At this meeting, an overview of the fire was provided by Prof. Kees van Weeren, who also supplied university-related links to publicly available photos, videos, and a written summary of the fire, which included eye-witness statements:

http://gallery.tudelft.nl/main.php?g2_itemId=1156738
http://www.buildingforbouwkunde.nl/BouwkundePortraitoftheFaculty/tabid/107/Default.aspx

The research team was also provided with basic floor plans and elevation drawings, along with photos and descriptions of the double-height studio areas.

The fire-specific university links were supplemented by various other internet sites, ranging from sites for photos, to discussion about the building, to building regulations in the Netherlands, including [8]:

http://www.flickr.com/search/?q=tu%20delft%20fire&w=all&s=int

http://www.vrom.nl/pagina.html?id=37435

Each of the public sites provided valuable information, which is included in the data collection effort, and will be invaluable to future research. This is particularly true of digital recordings (still and motion) of the event, which will help in understanding fire initiation and spread in the room of origin, fire spread beyond the room of origin, relative size and temperatures from the fire as it spread from compartment to compartment, and in understanding the collapse.

However, to facilitate a detailed analysis of the fire and structural response, many additional details are needed, such as outlined in section 2 above. Particularly, structural details (plans, calculations, materials), architectural layout and interior finishes (actual), type, location and arrangement of contents, fire protection systems installed, emergency response procedures, and fire ground operations. Due to ongoing investigations in the Netherlands, some of these data were not available in October 2008, and a second meeting was held in Delft in March 2009. At this time, a significant amount of additional information was gathered, including:

- Complete structural drawings
- Original structural calculations
- Architectural drawings
- MEP drawings
- Additional photos of the building, pre-, trans- and post fire, with pre-fire photos showing layout, contents of spaces, interior partitions and finishes, and related data.
- Material data for first item burning and adjacent materials.
- From interviews we conducted, an eyewitness account from one of the students who was involved in initial fire extinguishment activity.
- From interviews we conducted, an eyewitness account from a Faculty of Architecture staff member who was part of building's emergency response team and who observed the early stages of the fire and activated manual alarm.

- From interviews we conducted, an eyewitness account from a facilities management person who was in the building at the time of the fire.
- From interviews we conducted, eyewitness accounts from five fire service personnel intimately involved in fire extinguishment activity, including first responding fire team, second responding team, and command officers.
- From interviews we conducted, information from facilities management staff, including descriptions of building construction details, layout, modifications underway, material in vicinity of fire ignition, fire barrier construction, ceiling void arrangement, building systems, and related information specific to the Faculty of Architecture Building. In particular, this yielded specific information about the building details that may be significant to the event.
- Findings from other investigations conducted into the fire, including those focused on the first item burning and the emergency response.

To capture and save these data and information for future efforts to analyze the fire and resulting structural collapse, an internet-based database has been established by TNO. The aim is that, initially, the data will be available for participants of this effort to use in follow-up analyses of the fire and structural collapse, and ultimately, to be a publicly-available resource for fire and structures researchers outside of this team to use in analyses which they may choose to undertake. A secondary aim is to have this database become the foundation for an international database for significant building fire events, where data can be captured and saved for the purpose of scientific research and investigation on the fire performance of buildings.

Following are photos, drawings and sketches that are representative of data collected by this effort.

Fig. 3. Photograph of double-height studio with added mezzanine floor, furniture and materials typical of Faculty of Architecture building at time of fire [9].

Fig. 4. Photograph of interior partitions typical of Faculty of Architecture building at time of fire [9].

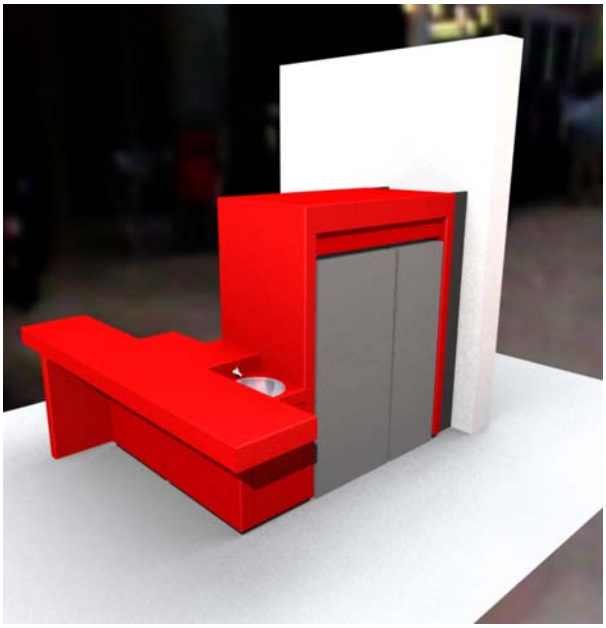

Fig. 5. Rendering of pantry area where coffee vending machine (source of fire ignition) was located within the Faculty of Architecture building [10].

Fig. 6. Photograph of intense burning during fire [2].

Fig. 7. Photograph of collapse area [11].

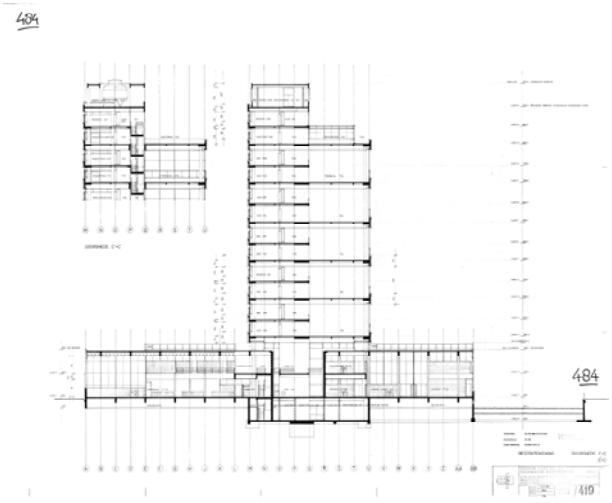

Fig. 8. Building elevation drawing [10].

4. Summary: The fire and subsequent collapse of a substantial portion of the Faculty of Architectural Building at the Delft University of Technology is significant in that fire-related collapse of structures is rare, with collapse of reinforced concrete structures even more so. This case is of particular interest since the fire started as any ordinary fire might – failure of an electrical appliance – and the fuel load in the building was not particularly high – yet the fire grew so rapidly that the fire department was unable to undertake successful fire control or extinguishing activities and a significant structural collapse occurred, resulting in the need to demolish the building for a total loss on the order of €100 Million. To help better understand why the fire grew so quickly to the point where fire-fighting efforts were not possible, and to investigate the mechanisms leading to the fire-related collapse in the North wing of the building, critical data have been collected and archived.

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6. References:

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[8] Tucholski, D. (2008). *A Preliminary Investigation into the Fire at the Faculty of Architecture Building Located at the Delft University of Technology*, Class Project, FP 571: Performance-Based Design, Worcester Polytechnic Institute, Worcester, MA.
[9] Photos compiled from TUD photographer (Foto's Berlageweg 1 bouw en gebruik TUD faculty of Architecture).
[10] TUD Facilities Management.
[11] From material compiled by Kees van Weeren.