Chapter 8:

FIRE PROTECTIVE DESIGN:

This is an outline version of the Powerpoint presentation shown in class.

A. GENERAL ISSUES IN FIRE PROTECTIVE DESIGN THAT AFFECT ALL BUILDING TYPES:

Primary Motivation in Design:

No. 1: Life Safety

no loss of life
safe evacuation of occupants

No. 2: Protection of Structure

maintaining integrity of building structure

Requirements for Combustion:

remove any one of heat, fuel and oxygen, and, no fire...

Main Issues:

- occupancy type
- occupant load
- building size
- construction type
- exit requirements
- fire resistance ratings
- fire separation

Occupancy Type:

- occupancy refers to the main intended use for a building or portion thereof
- can be classified for more than one major occupancy
- most hazardous use determines requirements for entire building, except if located entirely on top of one another
- certain occupancies can NEVER be combined

Occupancy Types List According to the Ontario Building Code:

Group	Division	Description
A	1	Production and viewing of performing arts
A	2	Not elsewhere classified
A	3	Arena type
A	4	Open air
B	1	Detention occupancies
B	2	Care and treatment occupancies
B	3	Care Occupancies
C		Residential Occupancies
D		Business and Personal Services
E		Mercantile
F	1	High Hazard Industrial
F	2	Medium Hazard Industrial
F	3	Low Hazard Industrial

Occupant Load:
- is the number of people is an estimate of the expected maximum use of a building or floor area, for the most hazardous use
- provides a basis to calculate the number of exits required
- can be used as a 'rule of thumb' basis for determining floor area requirements when designing

Construction Types:
Two Primary types of construction:
COMBUSTIBLE: ie. materials that burn easily and provide fuel for a fire (wood...)
NON-COMBUSTIBLE: ie. materials that do not burn or act as fuel (these include steel and concrete)

Combustible Construction:
- typically light wood frame construction or Post and Beam
- only able to be used on buildings less than 4 storeys and usually less than 600 m^2.
- used on buildings which require a fire resistance rating of 3/4 hour or less

Non-Combustible Construction:
- used on all other types of buildings
- used for fire resistance classifications of 3/4 hour or greater
- unprotected steel can only be used for ratings of 3/4 hour
- 1 hour or greater requires the use of concrete structural products or protection on steel products (gypsum, concrete, intumescent paint or other fireproofing)

Building Size:
A limit on the maximum area and number of floors based on:
- building use (occupancy type, hazard level)
- construction type (combustible/non)

- sprinklered or not (sprinklering allows for a doubling of area allowed)
- access for fire fighting (number of streets the building faces, hydrant location, standpipes...)

Determining Maximum Building Area:

Example: Maximum Building Area Group C up to 3 Storeys

No. of Storeys	Maximum Area (m^2)		
	Facing 1 Street	Facing 2 Streets	Facing 3 Streets
1	1,800	2,250	2,700
2	900	1,125	1,350
3	600	750	900

Building Height:

- taller buildings are more difficult to evacuate quickly so have more stringent limitations
- the gross floor area of single storey buildings will be greater than the g.f.a. of a multi storey building for the same use on the same site
- tall buildings require internal fire fighting equipment as trucks and ladders have a limit to the heights they can reach (usually 6 floors)

Exit Requirements:

- number and type dependent on occupancy type and load
- i.e. greater risk, more people, more exits
- every floor area must have 2 exits
- travel distance to the exit is limited
- dead end corridors (more than 6m) not permitted
- exits must be fire separated from the rest of the building they are serving

Exit through lobby:

One of the two exits may pass through a lobby space IF:

- lobby floor not more than 4.5m above grade
- path of travel does not exceed 15m
- rooms adjacent to lobby are fire separated (ie. doors and walls)
- lobby is not part of an interconnected atrium space

Spatial Separation:

Separation of buildings to isolate them from one another and to control the spread of fire by either:

- physical space between buildings, including control over openings and finishes
- physical barrier (wall) between buildings (firewall) or areas within a building (fire separation)

Fire Separation:

- is any wall, partition or floor assembly designed and built to prevent the spread of fire by restraining the passage of smoke, heat, gases and flame between compartments within one building
- assigned a fire resistance rating as required by the nature of the adjacent spaces

Firewalls

- are special fire separations -- continuous walls of masonry or concrete -- that prevent fires from within one structure from spreading to another structure
- must allow building to break away in a fire without destroying the integrity of the firewall
- can be used to divide a large building into smaller building areas
- fewer and more specially designed openings are allowed

Fire Resistance Rating:

- is the time in hours that an assembly can withstand the passage of flame and heat when exposed to fire under standard test conditions
- is characterized by the ability of an assembly to confine a fire or continue to perform a given structural function, or both, when exposed to fire
- these ratings are established by a government or certified private testing agency after rigorous testing; often assemblies and products will be required to have a ULC Rating (Underwriters Laboratories of Canada)

Fire Compartment:

- an enclosed space within a building that is separated from other parts of the building by surrounding continuous construction built as a rated fire separation
- between row houses or apartments, a one hour fire separation is required
- openings are allowed in the fire separation, but are limited in size and must be able to be closed

Fire Stopping:

- the blocking of concealed spaces in walls, ceilings and floors to slow down the undetectable spread of fire throughout the building
- prevents these chaseways from acting as chimneys

Unprotected Openings:

- any portion of an exterior building face that does not meet the fire resistance rating required for the building face (i.e. windows, doors, vent grilles)
- steel window frames, wired glass and glass block allow for a doubling of the OBC maximums
- sprinklering allows for a *doubling* of areas

Limiting Distance:

- refers to the distance between an exposing building face and the property line or to an imaginary line between two buildings on the same property.
- if the two buildings are the same (area of face and glass) the line will be midway; if they are different, the distance will be proportional

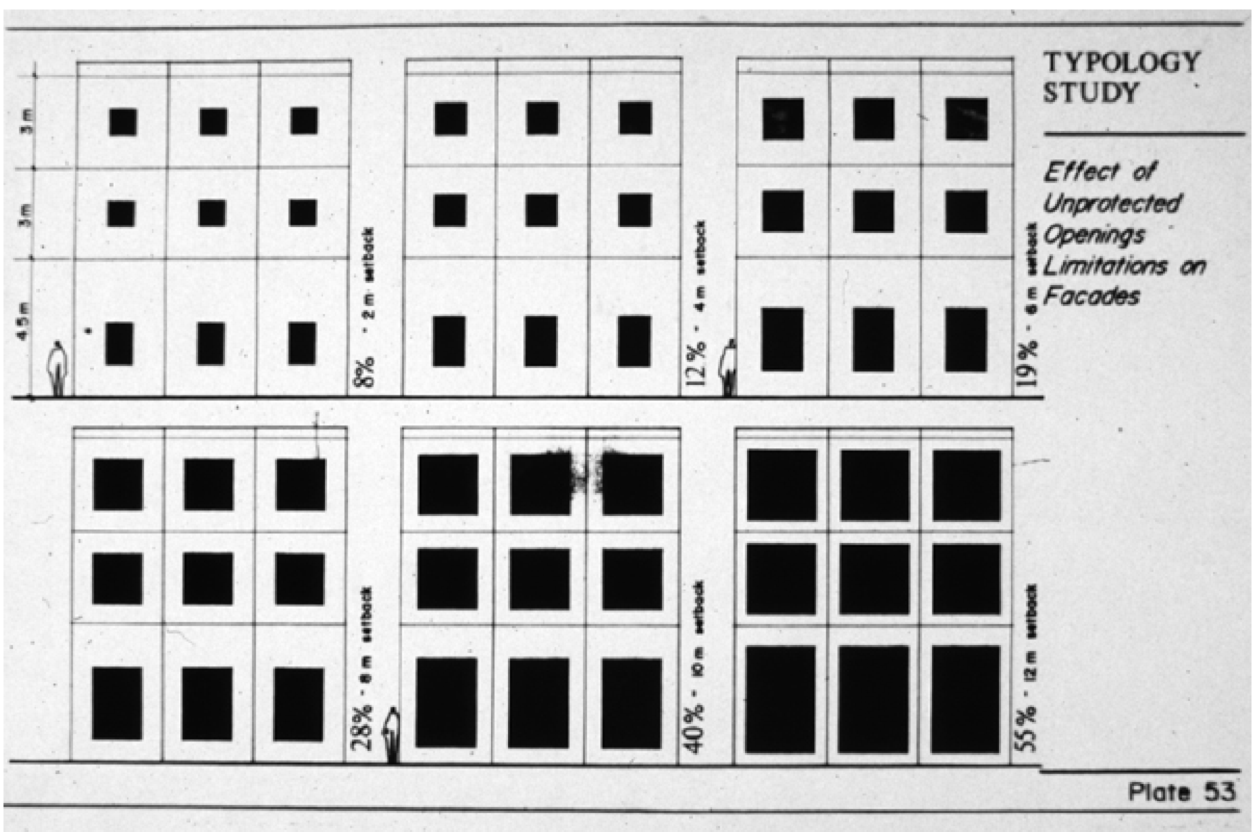
Exposing Building Face:

- is the area of an exterior wall of a building, between the ground level and the ceiling of the top storey, facing in one direction
- where a building is divided into "fire compartments", the exterior wall of each fire compartment becomes an exposing building face and is calculated separately

Sizing Unprotected Openings:

Limits are based on distance from property lines, as a % of the building face area; ie. for residential (50 s.m. building face):

- less than 1.2m setback allows 0%
- 1.2m setback allows 7%
- 1.5m setback allows 8%
- 2.0m setback allows for 10%
- 4.0m setback allows for 28%



B. HIGH-RISE FIRES:

High rise fires require a different attitude towards designing for structural safety to allow for evacuation. Smoke kills more than fire.

Learning from Large High-Rise Fires in Sao Paolo

- During the '70s and '80s Brazil suffered several high-rise fires with grave consequences, and unfortunately the problem was only properly understood after a number of large fires such as the Andraus Building (16 dead and 375 injured), the Joelma Building (79 Dead and 345 injured), and Grande Avenida Building (17 dead, 53 injured). These resulted in significant advances in fire safety such as new legislation, required inspections, codes and standards, public education and professional development, and statistics and investigations.
- Brazil normally used reinforced concrete for their high rise structures (not steel)
- most current high rise buildings are designed to last 2 hours in a "normal fire" (fuel is office furniture) which is principally to allow the people to escape before the building would collapse

MGM Grande, Las Vegas:
November 21, 1980:
84 people died and 700 were injured
Up to this point, worst fire death toll in US History

Joelma Building, Sao Paulo, 1974:

- 79 dead and 345 injured

Fire Design in High Rise Buildings: post 1970's disasters

- Structure to last no less than 2 - 3 hours
- remember that most people die from smoke inhalation, not fire
- elevators NOT to be used as they can malfunction due to electrical problems and shafts can fill with smoke
- stair wells must be fire-safe and pressurized to keep smoke OUT

Fire Tests for High-Rise Buildings:
Fire resistive products used to protect commercial hi-rise buildings are tested to ASTM E119. This standard requires that the fire resistive product protects the steel from reaching a limiting temperature during the time period required by the building codes. For the structural frame (columns and primary beams) the time period is 3 hours and the limiting temperature is 1200 F at any measured point on the column. For the primary beams the limiting temperature is 1300 F at any measured point on the beam. Floor beams require the same limiting temperature, but the time period is reduced to 2 hours. The test furnace follows a temperature curve so that the test specimen is exposed to a temperature of 1550 F at 1/2 hour, 1700 F at 1 hour 1850 F at 2 hours, 1960 F at 3 hours, and 2000 F at 4 hours. In other words under this test a fire resistive product with a 3 hour column rating, the highest temperature it was exposed to was 1960 F and only towards the end of the test.

Tests for Hydrocarbon Fires:

- On the other hand, fire resistive products used to protect refineries, petrochemical plants, etc, against hydrocarbon fires are tested to UL 1709. This standard requires that the test furnace reaches 2000 F in 5 minutes. Under this test then, the fire resistive product with a 3 hour column rating has been exposed to a temperature of 2000 F for 2 hours 55 minutes.
- You can see that the severity and speed of a hydrocarbon fire is much greater than a standard fire. The WTC towers were exposed to the severity of a hydrocarbon fire.

Concrete vs. Steel Structure??

- Sao Paulo Brazil has the unenviable record of having 3 of the most severe fires in the western hemisphere. These were all reinforced concrete buildings. 1/3rd of the floor area of the 21 story CESP 2 building suffered a total collapse from the 21st floor to the ground in 1987. The Andraus Building in 1972 and the Joelma Building in 1974, suffered extensive structural damage. The post tensioned concrete roof of the Falabela department store in the Plaza Vesuvias Mall in Santiago Chile collapsed onto the 2nd floor. All of these fires were of normal combustibles i.e., furniture, carpets, paper, etc, that are found in any office building, and none of these buildings experienced the tremendous impact or the added massive weight of a jet plane and passengers as the WTC did. News videos of the Andraus and Joelma fires show massive portions of the exterior concrete walls literally exploding apart during the fire.

Normal vs. Hydrocarbon Fires:

- The WTC was exposed to a jet fuel fire. <u>Jet fuel is not a normal combustible. It is a “hydrocarbon”,</u> a source of much higher temperatures that will negatively affect both steel and concrete much faster than normal combustibles would
- concrete exposed to the temperatures of a hydrocarbon fire will cause the moisture in the concrete to turn into steam so rapidly that the concrete will literally and explosively break apart
- when concrete is exposed to the temperature of a normal fire the concrete can flake apart under intense heat exposing the steel (it is protecting). Under a normal fire, moisture in the concrete has a better chance of coming out of the concrete without explosively spalling
- Under a hydrocarbon fire the moisture in the concrete is heated so rapidly that it immediately turns to steam and this literally causes the concrete to explode apart. Once this happens not only is the reinforcing steel exposed, but the concrete that holds the steel rigidly in place is gone as is it’s stability and load carrying capacity

WTC Collapse:

- “Each World Trade Center absorbed the impact of a jet with a shudder as they were designed to do, and stood.
- Inside, though, 2000-degree infernos started burning, fed by thousands of gallons of Jet Fuel”.

- “The south tower collapsed 56 minutes after impact. The north tower lasted an hour and 40 minutes”.
- The collapse was due in part by the fire, but largely because the impact of the jet took out a significant number of supporting columns
- The majority of WTC occupant deaths were the result of the destruction of the fire stairs below the top floors, at the point of impact. Most were filled with rubble, cutting off evacuation access.

WTC Structure:
- The plan arrangement of the WTC is typical of a tubular structure, columns spaced at 39” on center. Core was made of steel. Spray on fireproofing. Fire resistant gypsum board to protect the stairwells.

Remember:

- The Building Code and Fire Code provide Architects with a set of **MINIMUM** standards
- to be responsible, we must aim higher
- as the primary team leader in the design process, ***we weigh the value of human life against economics***