SELECTED TOPICS IN HIGH RISE MECHANICAL DESIGN

Simcoe Towers

Toronto and Dubai

Shangri-la Hotel

NORR | SWEGON ACADEMY

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INTRODUCTION

Topic

A discussion on mechanical building systems design practices in tall buildings. We will draw upon our experiences in building design in urban Canada, (specifically Toronto and surrounding region) and the Middle East, (specifically Dubai and the GCC).

Thesis

There are many factors which influence building design choices not just climate.

Study Sample

High rise residential, hospitality and commercial facilities
Toronto

Settled the 17th century
Capital of the province of Ontario
Business capital of Canada
Sprawling metropolis on the north shore of Lake Ontario
Population of 3.2 million
Climate of 4 seasons
    Schizophrenic summer
    Gorgeous Autumn
    Moderate winter with very cold periods
    Non existent spring

![Toronto Temperature Profile](image)
Dubai

The business capital of the United Arab Emirates
Trade, Finance, Stocks & Commodities
Regional travel hub
Tourist destination
Ruled by Maktoum family since the 18th century
Arabian Gulf to the west
Population of 1.3 million (mostly expatriates)
Climate: two seasons:
   Hot summers up to 50° C with high humidity.
   Spring and fall are more pleasant +/- 30° C
   Winter has lows of 15° C with occasional rain
INTRODUCTION

**Why**  **What**  **How**  **and Because**

**Why** - Safety

      Health

      Fit for purpose (meet comfort or process expectations)

      Economic viability (financial expectations, time)

      Effectiveness (Operations and Maintenance, energy efficiency, sustainability)

**What** - Movement of air, water etc

under the effects of gravity and powered delivery systems,

subject to understood principles of heat transfer, fluid mechanics and solid mechanics

**How** - Achieve the **Why** with the **What** under the influences of
INTRODUCTION

How - Achieve the why with the what under the influences of:

Because

Climate
International standards
Regional regulations
Investor/Developer financial expectations
Long term vs short term thinking
Market forces
  • Vendors – availability in the market
  • Labour costs
  • Material costs
  • Contractor – habits, capabilities
Maintenance likelihood
Regional habit
Types of ownership
Engineer’s position in the market
Aesthetic and functional project goals including shape
Physical Realities

Water in a typical 10 story building exerts a pressure of 3.3 bar.
A tall building can be considered to be a collection of shorter buildings.
Water in a 30 story tall building exerts a pressure of $3 \times 10 \text{ story} = 3 \times 3.3 \text{ bar} = 10 \text{ bar}$
INTRODUCTION

Pressure breaks

Upper building zone

High pressure zone

Medium pressure zones

Heat exchanger pressure break
INTRODUCTION

Pressure breaks

High pressure zone

Medium pressure zones

Water storage tank pressure break
Water, waste and other fluids move up and down the vertical axis. Pressure considerations must be managed.

Water can move orders of magnitude greater amount of energy than air.

Moving heating and cooling energy up and down a building requires less shaft space with water than with air.
In consideration of the foregoing we will examine the following mechanical design issues:

- Plumbing Systems
- Life Safety
- Heating, Ventilation & Air Conditioning
- Envelope Considerations
Water Supply

Dubai
Legacy of unreliability,
On site storage mandatory
Roof top tanks strongly incented

Concrete construction allows for
extra weight of water
Water Supply

Toronto
Robust and developed infrastructure
Generally reliable 4 -6 bar
Up to 5 +/- stories no supplementary pumping is required
Municipality takes responsibility for water supply adequacy, quality, etc.
System pressure regulation
Every 30 stories of residential building
Results in 10 bar additional pressure

Optimal delivery pressure of 1.5 – 2.5 bar
Maximum 5 bar

Pressure regulation is necessary
Domestic Hot Water

Distributed tank type
  • electric
  • gas

Distributed tankless
  • gas
  • electric

Central supply
  • gas
  • electric
  • Solar hot water

Dubai water chilling
Hot water from cold water taps
Cold water from hot water taps
Domestic hot water recirculation in high rise
PLUMBING SYSTEMS

Drainage and Venting

Toronto
comprehensive regulatory framework
well understood standard of practice
vendors / designer/ authorities aligned

Dubai
rudimentary regulatory framework
various international standards, BS, North American, EN, Chinese
vendors / designers / authorities not well aligned
Venting: not well understood
Installation of traps and floor drains – habit
Dual stack mandatory
Tall building drainage

Hydraulic jump – lowest floors of a drainage riser must not be connected directly to the high building riser.

10 pipe diameters (nominal I.D.)
= 1.5m for a 6" drain

*Hydraulic Jump (4.2.1.(2))*
NFPA National Fire Protection Association

common basis of design
widely accepted
comprehensive standards on commercial, institutional and industrial life safety issues

Water supply for fire fighting
automatic sprinkler system
fire hose system 4.5 bar residual pressure required

Toronto
low rise building directly supplied
fire pumps supplied from back up emergency power
separate sprinkler & standpipe pumps (usually)

Dubai
always pumped
electric fire pump backed up by direct diesel driven fire pump
results in combined sprinkler and fire standpipe systems
High Building Pressure Control – orifice plates

Application of sprinklers sometimes not well understood

Example: pendant sprinklers in exposed applications

Pendant sprinkler heads

Upright sprinkler head
Smoke Control

Smoke control specifically mandated for high buildings
Definition of high building

Isolation of fire floor
extraction from fire floor
pressurize floor above and below
differential pressure of 12 Pa
pressurize stairwell

Stairwell Pressurization
Must supply at various points in the stairwell so that
backpressure at exit doors is less than 133 N
Heating

Electric
Distributed hot water
Distributed gas
Distributed steam
Air source heat pumps
Water or ground source heat pumps

Low first cost but high operating cost
Very common
Not common due to safety concerns
Currently not common
Not compatible with very cold climates
Commonly applied

Dubai
No heating
Heating

Tall Building hot water supply to:
perimeter radiation
reheat of branch air terminals
Heating

Tall Building hot water supply to:
perimeter radiation
reheat of branch air terminals
overhead radiation
fan coil units
Heating

Tall Building hot water supply to:
- perimeter radiation
- reheat of branch air terminals
- overhead radiation
- fan coil units
- Unit heaters and convectors
- Heat pumps
Heating

Building hot water is typically supplied from a central hot water plant which consists of boilers, distribution pumps and piping systems.

In tall buildings pressure zoning is necessary to keep the installation economical since high pressure piping and components are more expensive.

Current practice is to design the heating system at minimum supply water temperature and maximum difference between the supply and the return in order to increase system efficiency. This must be optimized against system cost.

Supply water temperature is directly proportional to the output capacity of the heaters in the building spaces. Supply water is often scheduled against outside air temperature.
Heat pumps combined heating and cooling systems
Heating

Heat source: Ground connected geothermal heating boiler

Heat sink: Ground connected geothermal Cooling tower

Individual heat pumps are connected via a piping and water circulation system

Distributed compressors have noise and maintenance disadvantages
Fresh Air Supply

Toronto/Dubai: ASHRAE standards are a unifying norm. Both Toronto and Dubai have months of the year when natural ventilation is not possible.

Dubai ventilation shafts

**Toronto**
Filtered, heated, cooled, humidified
Heat recovery if dedicated fresh air system
“FREE COOLING” when combined with system supply air
Demand control just now starting to be utilized

**Dubai**
Sand trap, filtered, cooled, de-humidified
Heat recovery norm (mandatory)
Heat wheels, heat pipes
Constant volume – demand control starting to be utilized
Space humidity is an issue
VENTILATION

HUMIDITY CONTROL

Ventilation required to maintain comfort conditions in winter will require that moisture be added to fresh air supply to ensure that building is maintained at adequate humidity level.

Problem

Low humidity results in occupant discomfort and health issues and static electric shock problems

Mitigation

Add steam to air stream (energy to evaporate water provided by boiler)

Add atomized water to air stream (energy to evaporate water provided by air handling system)

Reduce load with heat wheel latent heat recovery
Building Exhausts

Commercial kitchen exhausts
regulated under NFPA 96

grease fires are very dangerous

16 gauge welded duct in fire rated enclosure

Canadian authorities → terminate 1.3 m above roof level

Special filtration technologies remove grease relaxes NFPA 96 requirements
Building Exhausts

Residential Kitchen Exhaust

Residential Kitchen Exhaust
Not regulated by NFPA 96
UAE culturally inclined to fried foods
Building Exhausts

Residential Kitchen Exhaust

Not regulated by NFPA 96
Culturally inclined to fried foods
Solution indirect central exhaust
**Washroom exhausts**

Central extraction is common in both Toronto and Dubai.

Traditional regulations in Dubai required 2 m X 3 m open to air shafts at kitchens and bathrooms – planning nightmare. Exterior plumbing pipes and open to air ventilation.

Common Toronto high rise residential solution – individual toilet/kitchen extraction fans controlled from light switch, ducted directly outside. Brick façade can accept grilles even if Architects do not want these – low cost. Curtain wall solutions in Dubai cannot accommodate.
High rise Residential Exhausts

Demand control extraction

Kitchen
Bathroom
Laundry
Toronto

Unitary equipment rather than
Air cooled chillers for smaller buildings

Split AC not common for larger commercial or residential buildings
(New advances in refrigerant circuits serving multiple zone units)
Chilled Water Supply
Toronto

Most larger buildings utilize water cooled chiller plants

Deep lake cooling
Chilled Water Supply

Dubai
- Air cooled chillers
- Water cooled chiller plants
- District cooling plants and distribution
Air Conditioning Commercial Buildings

**Variable Air Volume**
- Constant air supply temperature
- Vary air flow quantity to maintain space temperature

**Constant Air Volume**
- Vary supply air temperature to maintain space air temperature
Air Conditioning Commercial Buildings

Dubai

- some VAV horizontal fan coil units
- installation complexity
- maintenance issues
- low floor space impact
- improved floorplate efficiency
- Meat locker effect
Air Conditioning Commercial Buildings

Toronto Variable Air Volume

Central Units
- Large units located in mechanical rooms
- Conditioned supply and return air are ducted to floors served by the central unit. As the number of floors served increases, the floor area lost to duct shafts increases.

Compartmentalized
- Each floor has a small mechanical room (usually imbedded in the core) to serve that respective floor
- Cooling is distributed through the building by chilled water piping

Applied in conjunction with perimeter heating systems as discussed previously
Air Conditioning Commercial Buildings

Toronto Constant Air Volume

Fan Coil units
- Can provide heating, cooling or both
- Applied in conjunction with ventilation air supply systems

Heat Pumps
- Can provide heating, cooling or both
- Applied in conjunction with ventilation air supply systems
- Ground source or central plant supplemented
Air Conditioning Residential and Hospitality

Toronto

horizontal fan coil
vertical fan coils
Heat pumps
Air Conditioning Residential and Hospitality

Dubai

horizontal fan coil units
  • installation complexity
  • maintenance issues
  • low floor space impact – improved floorplate efficiency
**Winter Air Conditioning in Commercial Buildings**

Of a typical 3000 sq m building floorplate half will require year-round cooling.

In some building configurations outside air can be used. As buildings get larger this is less possible due to the large space required for ductwork compared to piping.

Require chilled water year-round:

- Could run the chilled water plant → Energy inefficient
- Could generate chilled water directly through heat exchange from outside air
  - Winterized cooling towers with heat exchangers
  - Dry coolers
Chinook Winds in Calgary

The weather can change from -25 deg C to +20 deg C in less than a day
Heating and Ventilation and Space Cooling and Humidity Control and Air Quality

Combined into a comprehensive Heating, Ventilation and Air Conditioning System

A buildings become larger they generally have a multi-purpose aspect. Commercial, residential and hospitality functions are often combined
Heat losses, Heat Gains and Solar Loads

- Thermal resistance
- Thermal breaks
- High Performance Glazing
Air Leakage and Ventilation

Effect by air tightness of the envelope and the pressure difference from inside to outside the building

For example: National Architectural Metal Manufacturer’s standard for a tight building is no more than 0.3 l/s/sqm at 75 Pa

Pressure difference is influenced by
- Wind
- Building system pressurization
- Stack effect
Stack Effect

Stack effect is the movement of air into and out of buildings that is driven by the buoyancy that occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences.

Particular concern in tall buildings
Climate
International standards
Regional regulations
Investor/Developer expectations
Long term vs short term thinking
Market forces
  - Vendors – position in the market
  - Available technologies
  - Labour – cost vs materials
  - Contractor – habits, capabilities
  - Maintenance likelihood
  - Habit
Type of ownership
Engineer’s position in the market
Architectural and functional goals
Thank you for your attention

Questions?