ANALYSIS & DESIGN OF WIND LOAD

Course Content:

✓ IDENTIFY the factors in wind speed and loading.

✓ DISCUSS the current technology of wind tunnel testing for high-rise building model.

✓ ANALYSE the structural response due to wind loading including sliding, overturning and torsion or twisting.

✓ DESIGN the wind load for highrise building according to MS1553.
CONTENTS

Part 1: Introduction - Wind Loads

Part 2: MS1553; 2002, Code of Practice on Wind Loading for Building Structures & Examples

Part 3: Examples
PART 1: INTRODUCTION

- Design wind pressure at the top of the tower were 19% lower than they should have been.

Ferrybridge Cooling Tower, UK (1965)
NATURAL DISASTER DUE TO WIND STORM
26 December 1996, Sabah - killed 270 people in.

12 February 1999, Kuala Lumpur - Several houses and buildings structures has damaged and destroyed by wind. Loses are estimated more than RM 250,000.

16 August 2004, Bukit Mertajam, Seberang Perai - Twenty vehicles damage because roof apartment falling down

28 August, Penang - Windstorm caused serious damaged to 25 houses but also injured people.

6 November 2004, wind storm has induced 40000 people affected in east cost of Peninsular Malaysia.

19 February 2005, Sungai Siput. Perak -38 numbers of house damaged due to windstorm.
Rain, storms damage houses

By P. Chandra Sagaran
chand@nst.com.my

SUNGAI SIPUT, Fri. — A routine visit to her granddaughter’s for tea every evening in the next village probably saved her life.

Mariam Putih Mat Darus, 80, who lives alone, yesterday evening found the roof of her home at Kampung Sungai Sejuk near here ripped off while some furniture and electrical appliances damaged during an hour-long storm.

“I was lucky I was not at home when the storm hit,” she said today.

Heavy rain and strong winds that hit Kampung Sungai Sejuk, Kampung Trosor, Kampung Datuk Sagor, Kampung Temin, Kampung Bekut and Felda Lasah over the past few days have damaged more than 30 houses but fortunately there have been no casualties.

Sungai Siput Umnio Youth division head Zamri Abdulrah said assistance for those affected would be sought from the district office and the social welfare department.

The families are staying with relatives while waiting for their homes to be repaired.

Kampung Sungai Sejuk village head Ismail Mat Jali said the storm, which began at 4.30pm yesterday, damaged more than 10 houses, including his.

Villager Norlia Madia, 60, from Kampung Trosor, was at work when the storm followed by heavy rain damaged her home.

STORM HIT: Mariam pointing to her damaged roof. — NST picture Ikhwan Munir
Longer power cut for storm-hit villages

TAPAH, Sun. — While electricity supply was resumed from 3am today for areas in south Perak hit by a blackout due to a lightning strike last night, things were different for several small clusters of villages near here.

Work was still going on by late afternoon today to re-connect their power supply cut due to the raging storm yesterday which uprooted trees and damaged power lines.

Houses were not spared, with more than a few bearing the brunt of the storm.

Perak Tenaga Nasional Berhad (TNB) general manager (distribution) Hairuddin Hussein said there was more work to be done before electricity could be restored.

Among the villages affected were Kampung Datuk, Kampung Raya and Jalan Damai.

Jalan Damai resident Azizah Rahmat, 68, said the 6.30pm storm was the worst she had experienced in her 45 years in the area.

“I rushed my seven grandchildren out of the house fearing that something might happen to them,” she said today. The front portion of Azizah’s house was damaged when a durian branch fell on it.
180 rumah rosak dipukul ribut

Oleh Rosdailiah Zainal

1 PEMILIHAN: Sebanyak 180 buah rumah mengalami kerusakan terutamanya ribut yang melanda selama kira-kira setengah jam sekitar 10.00 petang ketika hujan

AHLI Dewan Undangan Negeri 

(Akta Maraya, Daerah Negeri Iskandar), berbaikan pada ibu perupa kiai IB. Amin bin Ismail, yang akan diselidiki kias berdasarkan surat keputusan yang terkait dengan hujan dan ribut yang melanda pada petang itu.

Pada waktu itu, dua orang ibu perupa bernama Haji Abdurahman dan Haji Ahmad bin Ismail, yang merupakan ibu perupa kiai, meneruskan isu yang terkait dengan hujan dan ribut yang melanda pada petang itu.

Jawatan kerajaan memastikan bahawa ibu perupa tersebut akan diselidiki kias berdasarkan surat keputusan yang terkait dengan hujan dan ribut yang melanda pada petang itu.}
OKLAH REHIM

SINGA PETANI: "Saya berasa menyeluri kejadian itu apabila dia mengisi akibat kejadian selepas beberapa zink jatuh hampir tempat tidurnya." Saya bersyukur kerana dia tidak cedera," kata Zaiton Afi Manaf, ibu kepada Nor Aliu Natasha Ismail, 5, antara marga kejadian ribut di Kampung Sungai Deraka, Kota Kuala Muda, dekat siti, awal pagi semalam.

Dalam kejadian ribut serta hujan lebat yang terjadi sekitar 7.30 pagi itu, mengurungkan tujuh rumah rosak termasuk empat darinya rosak telak.

Zaiton, 50, berkata, ketika kejadian awalnya itu masih tikai dalam kelambu di ba bagian depan rumahnya.

"Saya tidak mampu berbuat apa apabila penciptaan Allah yang terangai akibat kejadian kejadian itu," katanya ketika ditemui di ru malahnya semalam.

Bagaimanapun, semua 11 penginjil rumah itu terselamat.

Seorang marga ribut, Fariza Ahmad, 43, berkata kejadian ribut yang berlaku begitu pantas kira-kira 10 minit itu menyebabkan bumbung rumah ketika dia bersama anaknya, Hazari Mohd Khalid, 19, sedang bersenam.

"Saya dengar bunyi dengan letupan bumbung dan da lam sekejap mata bumbung rumah kami diterbangkan ribut dan jatuh hampir 100 meter dari rumah," kata dia.

Dis bersyukur kerana ke-

jaduan, dua anaknya tiada di rumah kerana ke sekolah.

Semasa itu, dalam ke-

jaduan sama, 10 keping bumbung bangunan Sekolah Ke-

bangsaan (SK) Haji Sulaiman turut diterbangkan ribut.

Bagaimanapun, tadi yang tercedera kerana ketika ke-

jadiuan semua pelajar sedang berada di kantin sekolah.

Semasa ini, Abi Danan Unggah, Negeri Adun, kawasan Puntai Merdeka, Batu, Dr Shafiz Sidek, ke-

nya diterbangkan ke-

mua ribut akan dibantu.

Dia menambahkan mana-


10 keping bumbung bangunan Sekolah Kebangsaan (SK) Haji Sulaiman turut diterbangkan ribut.
Bumbung diterbang ribut

Beberapa rumah, pusat beli-belih di Putrajaya roak dilanda ribut, hujan lebat sebabkan banjir kilat

Oleh Hafiz Ilham

PUTRAJAYA: Hujan lebat disertai ribut petir lebih satu jam, petang semalam menyebabkan beberapa rumah kediaman dan pusat beli-belih terkecut muka di sini, digemari air akibat bumbung yang diterbang bangkan angin.

Kejadian yang bermula kira-kira jam 3.30 petang itu turut menyebabkan banjir kilat di sekitar Putrajaya, sekitar beberapa butang pokok tumbang serta dua kenderaan termasuk sebuah mosik dan kereta rosak akibat ditumpak apabila genting yang jatuh dari pangsapuri.

Bagaimanapun, tiada kecederaan dilaporkan.


Pembantu am di Kemen terian Kemajuan Luar Bandaran Wilayah, Norain Arshad, 22, yang tinggal di tingkat 16, Blok B, Pangsapuri Putra Damai berkata, kejadian itu disebabkan sebab pulang ke rumah kira-kira jam 5.30 petang.

"Ketika tiba di rumah, saya melihat rakan sedang mengeringkan air yang berta kung di ruang tamu rumah. Apabila memasuki bilik saya, air sudah meluap hingga manakala seluruh ruang bilik termasuk tamu dan pakaian basah.


Norain yang menyeru rumah itu sejuk setahun lalu bersama enam lagi rakan, su-

SITI RAHAYU...agak cemas
dah memaklumkan menger itu ke pada tuam rumah, namun pemilik rumah itu memaklum

kan dia sudah memberitahu pihak penyelenggaraan.

"Tetapi sehingga kini, tiada tindakan segara dambil untuk mengatasi masalah itu. Sehubungan kami rasa setiap kali hujan lebat," katanya.

Sementara itu, Siti Rahayu Abu Bakar, 38, yang tinggal di tingkat empat, Blok B, Pangsapuri Presint 8, berkata sepatutnya hujan lebat berserta angin kencang, dia terus menghubungi anaknya yang tinggal di rumah supaya menutup semua tingkap dan pintu.

"Panggilan pertama saya di jawab, tetapi selesa kekata saya menghubungi semula bagi memastikan keselamatan tanpa, namun panggilan te

lefon saya tidak terjawab me nyelubung, saya agak cemas sekita," katanya.
Bumbung tercabut

Laporan dan foto Sahril
Kamaruddin

BANG: "Saya tems peluang an azan kera tidak tahu apa lagi patut saya buat selepas seluruh rumah bergegar dan bumbung tercabut diter bangkan angin disebabkan ribut terluar kuat," kata Rosli Din.

Roslil, 45, antara pemilik rumah yang rosak akibat kejadian ribut di Kampung Padang g Cik Mas, Mu kim, Pulau, dekat sini, kita-kira jam 7 malam kal marin.
Menurutnya, ketika kejadian dia menikmati minum petang bersama anaknya di dapur dan mereka merasa cang hendak ke masjid bagi memasak solat Maghrib.
"Tiba-tiba saya nampak angin putih berpusing-pu sing masuk ke ruang tanu rumah dan dalam sekellip mata atas rumah diterbang kan. Saya sempat memeluk anak saya selepas bumbung terbang angin sejauh 20 meter.
"Kami kemudian berdiri di pinggir ruang dapur kerana bimbang ang rumah runtuh dan ketika itu saya melangkatkan azan." kataanya sembil mem beriha, hujan lebat ber terusan kira-kira kira-kira 30 minit.
Roslil berkata, akibat ribut itu pihaknya mengalami kerugian kira-kira RM8,000 berikutan banyak peralatan rumahnya rosak.
Seorang lagi penduduk, Mohd Nazir Samah, 41, ber kata ketika kejadian itu dia pergi menziarah i istirinya di rumah mentuanya di Sik, Ke dah.
"Ketika kejadian, hanya dua anak saya di rumah iaitu Mohd Hafiz, 14, dan Moh ham ad, 7.
"Mujur anak saya selamat walaupun sebuahan rumah saya rosak teruk akibat di hantap pokok macang. Se mua barang dalam rumah rosak kerana dibasahi air," katanya.
Kejadian ribut itu juga menyebabkan beberapa pokok tumbang dan menghalang ja lan utama untuk ke kampung berkerana.
Bagaimanapun, dengan bantuan Tenaga Nasional Berhad (TNB) Baling, usaha memperbaiki pendawai an elek trik serta membersihkan pok ok yang tumbang merin tangi akan dijalankan.
Sementara itu, Anggota Dewan Undangan Negeri (Adun) Bayu, Azme Che Hussain, yang melawat mengatakan menimbulkan kerajaan negeri menyelaraskan bantuan dengan segera.

BAIKL... mangsa menunjukkan rumah yang rosak.
<table>
<thead>
<tr>
<th>Site, State</th>
<th>Date</th>
<th>Time</th>
<th>Wind Speed</th>
<th>Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuala Perlis, Perlis</td>
<td>8-Oct-08</td>
<td>8.00 pm.</td>
<td></td>
<td>Chuping</td>
</tr>
<tr>
<td>Sik, Kedah</td>
<td>28-Mar-09</td>
<td>Evening</td>
<td></td>
<td>Alor Setar Station</td>
</tr>
<tr>
<td>Alor Setar, Kedah</td>
<td>25-Mar-09</td>
<td>-</td>
<td>79.92km/hr</td>
<td>Alor Setar Station</td>
</tr>
<tr>
<td>Batu Lanchang, Penang</td>
<td>4-Apr-05</td>
<td>4.30 pm.</td>
<td></td>
<td>Bayan Lepas</td>
</tr>
<tr>
<td>Sungai Dua, Penang</td>
<td>20-Jun-07</td>
<td>1.44 pm.</td>
<td>79.636 km/hr</td>
<td>Bayan Lepas</td>
</tr>
<tr>
<td>Taiping, Perak</td>
<td>14-Aug-09</td>
<td>5.00 pm.</td>
<td></td>
<td>Hospital Taiping</td>
</tr>
<tr>
<td>Putra Jaya, Selangor</td>
<td>4-Apr-08</td>
<td>3.30 pm.</td>
<td></td>
<td>Subang</td>
</tr>
<tr>
<td>Kampung Malaysia Raya, Kuala Lumpur</td>
<td>28-Nov-09</td>
<td>4.15 pm.</td>
<td>15.9 m/s</td>
<td>Subang</td>
</tr>
<tr>
<td>Seremban, Negeri Sembilan</td>
<td>1-Jan-10</td>
<td>5.30 am.</td>
<td></td>
<td>Hospital Seremban</td>
</tr>
<tr>
<td>Kota Melaka, Melaka</td>
<td>1-May-07</td>
<td>-</td>
<td></td>
<td>Melaka</td>
</tr>
<tr>
<td>Parit Jawa, Muar, Johor</td>
<td>21-Oct-09</td>
<td>1.45 am.</td>
<td>48.6 km/hr</td>
<td>Senai</td>
</tr>
<tr>
<td>Johor Bahru, Johor</td>
<td>19-Jul-07</td>
<td>11.15 am.</td>
<td></td>
<td>Mersing</td>
</tr>
<tr>
<td>Rompin, Pahang</td>
<td>28-Sep-09</td>
<td>4.00 pm.</td>
<td></td>
<td>Muadzam shah</td>
</tr>
<tr>
<td>Kota Bharu, Kelantan</td>
<td>2-Oct-09</td>
<td>-</td>
<td></td>
<td>Kota Bharu</td>
</tr>
<tr>
<td>Kota Bharu, Kelantan</td>
<td>22-Nov-09</td>
<td>-</td>
<td></td>
<td>Kota Bharu</td>
</tr>
<tr>
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<td>30-Sep-09</td>
<td>3.30 pm.</td>
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<td>Kota Bharu</td>
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<td>Besut, Terengganu</td>
<td>24-Apr-09</td>
<td>5.00 pm.</td>
<td>52.56 km/hr</td>
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<tr>
<td>Kuala Terengganu, Terengganu</td>
<td>21-Nov-09</td>
<td>Noon</td>
<td></td>
<td>Kuala Terengganu</td>
</tr>
<tr>
<td>Tawau, Sabah</td>
<td>24-Nov-07</td>
<td>-</td>
<td>50km/hr</td>
<td>Tawau</td>
</tr>
<tr>
<td>Lahad Datu, Sabah</td>
<td>19-May-09</td>
<td>Night</td>
<td></td>
<td>Tawau</td>
</tr>
<tr>
<td>Papar, Labuan</td>
<td>28-Sep</td>
<td>-</td>
<td>60km/hr</td>
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<tr>
<td>Kapit, Sarawak</td>
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<td>7.30 pm.</td>
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<td>Kuching</td>
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<tr>
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<td>15-Aug-09</td>
<td>-</td>
<td>40.7km/hr</td>
<td>Kuching</td>
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</table>
### Top 10 Natural Disasters in MALAYSIA

**sorted by economic damage costs affected from 1979 to 2008**

<table>
<thead>
<tr>
<th></th>
<th># of Events</th>
<th>Killed</th>
<th>Total Affected</th>
<th>Damage US (000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drought</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td>1</td>
<td>-</td>
<td>5000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Epidemic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unspecified</td>
<td>12</td>
<td>98</td>
<td>225029</td>
<td>978,000 (1)</td>
</tr>
<tr>
<td>Arbovirus</td>
<td>5</td>
<td>487</td>
<td>28254</td>
<td>-</td>
</tr>
<tr>
<td>Diarrhoeal/Enteric</td>
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<td>-</td>
<td>607</td>
<td>-</td>
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<td>Meningitis</td>
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<td>Respiratory</td>
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<td>Unknown</td>
<td>2</td>
<td>4</td>
<td>988</td>
<td>-</td>
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<tr>
<td><strong>Flood</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flash Flood</td>
<td>3</td>
<td>19</td>
<td>130600</td>
<td>22,000</td>
</tr>
<tr>
<td>Flood</td>
<td>9</td>
<td>54</td>
<td>71118</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Slides</strong></td>
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<td></td>
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<tr>
<td>Landslide</td>
<td>4</td>
<td>152</td>
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<td>-</td>
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<tr>
<td><strong>Wave / Surge</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsunami</td>
<td>1</td>
<td>80</td>
<td>5063</td>
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<tr>
<td><strong>Wild Fires</strong></td>
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<td></td>
</tr>
<tr>
<td>Forest</td>
<td>4</td>
<td>-</td>
<td>3000</td>
<td>302,000 (3)</td>
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<tr>
<td><strong>Wind Storm</strong></td>
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<td></td>
</tr>
<tr>
<td>Storm</td>
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<td>Typhoon</td>
<td>2</td>
<td>272</td>
<td>6291</td>
<td>53,000 (4)</td>
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</tbody>
</table>

Source: "EM-DAT: The OFDA/CRED International Disaster Database"
## Top 10 Natural Disasters in INDONESIA

**sorted by economic damage costs affected from 1979 to 2008**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th># of Events</th>
<th>Killed</th>
<th>Total Affected</th>
<th>Damage US (000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>Drought</td>
<td>6</td>
<td>1266</td>
<td>1083000</td>
<td>89,000</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Earthquake</td>
<td>70</td>
<td>11071</td>
<td>5078535</td>
<td>4,476,276 (3)</td>
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<tr>
<td>Epidemic</td>
<td>Anthrax</td>
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<td>1</td>
<td>267</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Arbovirus</td>
<td>9</td>
<td>2076</td>
<td>136460</td>
<td>-</td>
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<tr>
<td>11</td>
<td>Diarrhoeal/Enteric</td>
<td>11</td>
<td>600</td>
<td>17641</td>
<td>-</td>
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<td>11</td>
<td>Malaria</td>
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<td>504000</td>
<td>-</td>
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<tr>
<td>11</td>
<td>Rabies</td>
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<td>15</td>
<td>203</td>
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<tr>
<td>11</td>
<td>Respiratory</td>
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<td>87</td>
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<tr>
<td>11</td>
<td>Unknown</td>
<td>1</td>
<td>672</td>
<td></td>
<td>-</td>
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<tr>
<td>Flood</td>
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<td>3013819</td>
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<td>11</td>
<td>Flash Flood</td>
<td>13</td>
<td>1210</td>
<td>827209</td>
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<tr>
<td>11</td>
<td>Flood</td>
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<td>2488</td>
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<td>Slides</td>
<td>Landslide</td>
<td>36</td>
<td>1570</td>
<td>384647</td>
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<tr>
<td>11</td>
<td>Volcano</td>
<td>9</td>
<td>35</td>
<td>122110</td>
<td>8,000</td>
</tr>
<tr>
<td>11</td>
<td>Explosive Eruption</td>
<td>11</td>
<td>26</td>
<td>586</td>
<td>517683</td>
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<td>11</td>
<td>Volcano</td>
<td>26</td>
<td>586</td>
<td>517683</td>
<td>336,190</td>
</tr>
<tr>
<td>Wave / Surge</td>
<td>Tidal wave</td>
<td>2</td>
<td>550</td>
<td>2023</td>
<td>-</td>
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<tr>
<td>11</td>
<td>Tsunami</td>
<td>2</td>
<td>166510</td>
<td>568441</td>
<td>4,506,600 (2)</td>
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<tr>
<td>Wild Fires</td>
<td>Forest</td>
<td>9</td>
<td>300</td>
<td>3034478</td>
<td>9,329,000 (1)</td>
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<tr>
<td>Wind Storm</td>
<td>Cyclone</td>
<td>3</td>
<td>2</td>
<td>2238</td>
<td>-</td>
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<tr>
<td>11</td>
<td>Storm</td>
<td>2</td>
<td>4</td>
<td>12400</td>
<td>-</td>
</tr>
</tbody>
</table>

*Source: EM-DAT. The OFDA/CRED International Disaster Database*
Structural loads are forces, deformation or acceleration applied to a structure or its components.
TYPES OF LOAD

1. **Dead Load** - loads are relatively constant over time.
   - also known as permanent or static loads

2. **Live Load** - dynamic or impose or moving loads, temporary of short duration.
   - Consideration: impact, momentum, vibration, slosh dynamic of fluid
TYPES OF LOAD

- The building materials impose dead loads \((\text{fixed, vertical})\)
- The occupants and contents impose live loads \((\text{variable, mostly vertical})\)
- Wind and earthquake impose live loads \((\text{variable, mostly horizontal})\)
LOAD DISTRIBUTION SYSTEM

All types of loads can be considered as:

- **vertical load**
- **lateral load**

**Vertical loads transfer through:**

- **Bearing wall**
- **Column**
- **Core**
- **Diagonal frame**

**Lateral loads transfer through**

- **Shear wall**
- **Slab → core**
- **Beam → Core/Column**
- **Diagonal Frame**
Wind load has the ability to bring a building to sway.
- Involve both *pressure* and *suction*.
- Important for tall buildings
- But also important for low buildings - bracing purposes
- **Wind velocity increases** with the increase of *height*
VARIATION OF WIND LOAD WITH THE VARIATION OF FORMS

Round shape
Minimum wind pressure

Irregular shape
Maximum wind pressure

Plan view
WIND LOADS ON BUILDINGS

- Pressure on the windward face
- Suction on other faces
- Suction on low-pitched roofs - < 30°
- Buildings need bracing and tying down
- Wind can come from any direction
WIND LOADS ON BUILDINGS

- may need to weigh down roof
WIND LOADS ON BUILDINGS

- Wind tends to overturn a tall building
- Acts as a vertical cantilever
FACTORS IN WIND SPEEDS

- General wind speed in the region (8 - 20 m/s) - pressure varies with square of the speed
- Local topography affects wind patterns
- Wind speed **increases with altitude**
- Wind speed decrease with terrain roughness
FACTORS IN WIND SPEEDS

- Shelter from anything permanent will reduce loads
- Shape of building affects loads (Box vs streamlined)
WIND LOADS ON ELEMENTS

- Min wind pressure in **MS1553** = 0.65 kPa
- Wind Force = Multiply by the area exposed to wind
WIND LOADS

- Dependent on the geographical location, height, type of surrounding physical environment, shape and size of building as well as many other factors.
- Although exact prediction of the wind load magnitude on a building is not possible, various building codes provide a very clear and conservative method for designing for wind loads.
- Wind and earthquake loads are applied as lateral or horizontal forces on the building.

Earthquake loads:
are highly unpredictable and their analysis is based on dynamic and probabilistic methods. However, most building structures are designed based on codes, which have provision for resisting moderate earthquake without structural damage and resisting major earthquake without collapse.
Deflection

All structures experience stress and undergo a limited amount of deflection when subjected to loading. A structure’s deflection under the dead load is only in the vertical direction with no lateral deflection at all. Vertical deflection can be in the form of bending in the horizontal spanning members such as beams and slabs and shortening of vertical load bearing members such as columns and walls.
STRUCTURAL RESPONSE

Deflection (continue)

When the live load is added to the structure, the produced stresses and the resulted deflections become much higher. The horizontal loads such as wind load and earthquake loads can produce large lateral displacement of the overall structure, which in turn will result in deformation of structural members locally.

Excessive deflections are undesirable in a building because they can result in damage of the building components and create structural problems. Deflection limits imposed by various building codes. These limits are based on the load types and the structural member.
Overall Structural Stability

If the structure or its foundation is not properly designed or constructed the overall structural system can lose balance and fail.

This failure can result in:

1. Sliding
2. Overturning
3. Member Failure
1. Sliding

Sliding is mostly due to the effect of lateral forces on inadequately designed foundation systems.

If a structure’s foundation is not large enough to withstand lateral forces or if the structure and its foundation do not interact sufficiently, under extreme loads the overall structure will move as a complete unit resulting in severe structural damage to the building.

To prevent sliding the foundation must be placed over a wide area or pile foundations can be used.
2. **Overturning**

Usually due to the effect of lateral forces, however in some cases the gravity forces can set the structure out of balance and create failure.

Overturning is a structural failure that is normally associated with tall and slender buildings with relatively small foundations.

In most cases a well-designed, large and rigid foundation can provide the required resistance for balancing the loads and assuring safety against overturning.
TYPES OF FAILURES

3. Members failure
   The existing member failed to carry the load/burden.
TYPES OF FAILURES

Torsion or Twisting:

- most likely induced by the action of lateral forces, like wind and earthquake load, although gravity load can be a problem if the structure is not properly designed.

- The lateral forces acting as couples at the base of the structure create a twisting motion, which is called torsion.

- The torsion failure is significantly more of a problem for non-symmetrical structure in which the centre of gravity of the structure does not coincide with the centre of mass.

- In seismic regions uniform distribution of structural elements like floors, walls, and columns is highly recommended.
<table>
<thead>
<tr>
<th>Types of Failures</th>
<th>Structural Responses in Preventing Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overturning/Sliding</td>
<td>Wide Heavy Footings/Piles</td>
</tr>
<tr>
<td>Lateral Racking/Twisting or Torsion</td>
<td>Cross Bracing/Rigid Connection/Shear Walls</td>
</tr>
<tr>
<td>Members Failure</td>
<td>Member Sizing</td>
</tr>
</tbody>
</table>
TYPES OF FAILURES

- Sliding/Overturning

  ![Wind or Earthquake Forces](image1)

  ![Overturning](image2)

  ![Sliding](image3)

- Preventing failures

  ![Wide/Heavy Footings](image4)

  ![Piles](image5)

  ![Preventing Overturning or Sliding](image6)
TYPES OF FAILURES

- Lateral Racking/Twisting/Torsion

Preventing failures

- Bracing: structural element for positioning, supporting, strengthening or restraining the member of a structural frame.

- Shear wall: Vertical diaphragm or wall acting as a thin, deep cantilever beam in loads to the ground foundation.

Wind or Earthquake Forces

Gravity Loads

Lateral racking

Twisting

Cross bracing

Rigid connections (frame action)

Preventing Lateral Racking or Twisting

Shear walls
TYPES OF FAILURES

- Member Failures

Gravity Loads

Preventing failures

Member sizing
Proventing Member Failures
LIMITATIONS OF CODES

- Not consider tornadoes and typhoons
- Covers only building +/- 200m high
- Structures with roof spans less than 100m
- Not off-shore structures, bridges and transmission towers
Current technology is based on simulating boundary-layer (synoptic) wind profiles.

Modelled building + surrounding structures + topography are geometrically similar to full scale.

Instrumentations are consistent with the required measurement.

Less effect of terrain and topography.
WIND TUNNEL TESTING: 450 KW WIND TUNNEL

- UBN Complex
- Kuala Lumpur 1982
- Aeroelastic test
WIND TUNNEL TESTING: 450 KW WIND TUNNEL

- Menara MPPJ
- Petaling Jaya 1983
- Aeroelastic Test
- Cladding pressure
WIND TUNNEL TESTING: 450 KW WIND TUNNEL

- Meara Safuan
- Kuala Lumpur 1984
- Aeroelastic test
- Cladding pressure
- Environmental wind study
WIND TUNNEL TESTING: 1 MW WIND TUNNEL

- Penang stadium
- 1997-1998
- Aeroelastic
- Pressure study with correlations (effective static wind loads)
WIND TUNNEL TESTING:
450 KW WIND TUNNEL

- Batang Baram Bridge
- Sarawak
- 1997
- section model test
WIND TUNNEL TESTING:
1 MW WIND TUNNEL

- Batang Baram Bridge
- Sarawak
- 1997
- Aeroelastic model of full bridge and erection stages
WIND TUNNEL TESTING:
450 KW WIND TUNNEL

- University Teknologi Petronas (UTP)
- Troth 1999
- cladding pressure
- area-average pressure
WIND TUNNEL TESTING AT NUS

- Meara Taming Sari
- Melaka, 2003
- cladding pressure
- aeroelastic
SUMMARY

- Not all extreme winds are boundary-layer winds
- Thunderstorm downburst winds are dominant contributor to extreme winds in equatorial climates near ground level
- Synoptic winds may be dominant at greater heights - tall buildings
- Storm types must be separated in extreme value analysis
- Full-scale measurements of vertical and horizontal profiles in downbursts are required
- Potential for laboratory and numerical simulation of flow over buildings, topography
VIDEO 1
ULTRASONIC WIND SENSOR
UWS Position at Seberang Jaya Telecommunication Tower

<table>
<thead>
<tr>
<th>level</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>45.72</td>
<td>75.28</td>
<td>97.23</td>
</tr>
</tbody>
</table>
Telecom Tower, Seberang Jaya
Malaysia has developed their code of practice MS 1553:2002 on wind loading for building structure.

MS: 1553:2002 has been base from Australia Standard AS 1170.2 based on similarity of wind climate (Sundaraj, 2002).

The code was developed using 23 meteorological all over Malaysia and the basic wind speed for Malaysia was established.

In year 2002 under research grant of wind profile study, three ultrasonic wind sensors were installed in Seberang Jaya Telecommunication Tower.
MS 1553: 2002 Overview

1998 IRPA Grant

1998 Wind Group Committee start to build Code of practice of wind loading

Determine the coefficients of exposure pressure and dynamic pressure to Malaysia building structure
S.F. Senin, 2000

Wind Data Validation Determination of basic wind speed in Malaysia
G. Sundaraj, 2002
- Provide basic wind speed for Malaysia area

April 2002 - Wind sensor were installed Seberang Jaya Telecommunication Tower

Non Stationary and Stationary of data
Kevin C.N. 2004

Analysis of Extreme wind speed for short period record
N.I Ramli, 2004

2002 - MS 1553: 2002

Wind Speed Vertical Profile, Validation and Determination of Terrain Height Multiplier
N.I. Ramli, 2005

MS 1553: Code of Practice on wind loading in Malaysia
EFFECT OF WIND LOADING BUILDING
WHAT WILL HAPPEN?
The most common lateral load considered in building design is wind load.

Wind load vary in intensity depending on the building's geographic location, elevation, degree of exposure, relationship to nearby structures, building height, size and shape.

The dynamic effect of wind load is usually analyzed as an equivalent static load in most small and moderate-sized buildings.
Wind loads have become particularly significant because of the increasing number of high-rise buildings.