

清华大学研究生课程——《灾害学》

# 风灾

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1

清华大学研究生课程——《灾害学》

## 内容提要

- 风的类型与分类
- 风灾对建筑物的影响
- 工程结构抗风设计
- 防风减灾对策与风振控制

2

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## 结构风工程

- 1879年Tay桥事故后开始引起重视
- 二十世纪50年代后期开始成为一门独立的学科
- 1963年后开始召开国际风工程会议
- 我国80年代后，随着大量新兴高层建筑和大跨桥梁的修建而得到迅速发展

3

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## 风速仪

- 机械风速仪
- 价格低廉
- 只能测量水平方向的风速



4

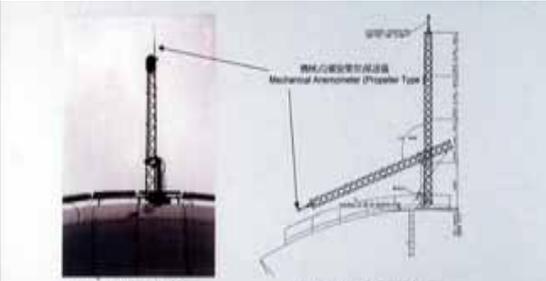
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## 风速仪

- 超声波风速仪
- 价格高
- 能测量各个方向的风速



5



机械式螺旋桨型风速仪  
Mechanical Anemometer (Propeller Type)

机械式螺旋桨型风速仪前视图  
Detail of Mechanical Anemometer (Propeller Type)

青馬大橋南面橋塔頂上的機械式(螺旋槳型)風速儀  
Mechanical Anemometer (Propeller Type) on South Bridge-Tower Top of Tsing Ma Bridge (at Ch 25 000)



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## 大气边界层

- 地面摩擦对空气产生阻力，使空气流动速度变慢，超过一定高度就可以忽略地面摩擦，该高度称为边界层；

边界层高度

9

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## 平均风速剖面

- 对数率
- 指数率

	开阔地面	郊区	大城市中心
$\alpha$	0.16	0.28	0.40

10

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## 对数率

图 2-2 城市覆盖层上面的和内部的风速曲线示意图

11

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## 指数率

100	100	100	100
50	50	50	50
25	25	25	25
12.5	12.5	12.5	12.5
6.25	6.25	6.25	6.25
3.125	3.125	3.125	3.125
1.5625	1.5625	1.5625	1.5625
0.78125	0.78125	0.78125	0.78125
0.390625	0.390625	0.390625	0.390625
0.1953125	0.1953125	0.1953125	0.1953125
0.09765625	0.09765625	0.09765625	0.09765625
0.048828125	0.048828125	0.048828125	0.048828125
0.0244140625	0.0244140625	0.0244140625	0.0244140625
0.01220703125	0.01220703125	0.01220703125	0.01220703125
0.006103515625	0.006103515625	0.006103515625	0.006103515625
0.0030517578125	0.0030517578125	0.0030517578125	0.0030517578125
0.00152587890625	0.00152587890625	0.00152587890625	0.00152587890625
0.000762939453125	0.000762939453125	0.000762939453125	0.000762939453125
0.0003814697265625	0.0003814697265625	0.0003814697265625	0.0003814697265625
0.00019073486328125	0.00019073486328125	0.00019073486328125	0.00019073486328125
0.000095367431640625	0.000095367431640625	0.000095367431640625	0.000095367431640625
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## 指数率的系数

$$\frac{\bar{v}(z)}{v_b} = \left(\frac{z}{z_b}\right)^\alpha$$

地面粗糙度	描述	$\alpha$
A	近海海面、海岛、海岸及沙漠地区	0.12
B	田野、乡村、丛林、丘陵及房屋比较稀疏的乡镇和城市郊区	0.16
C	密集建筑群的城市市区	0.22
D	密集建筑群且房屋较高的城市市区	0.30

13

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## 风速与风谱

- 实际风速时程曲线
- 平均风速

14

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## 基本风速

- 标准地面粗糙度
- 标准高度
  - 10m
- 标准重现期
  - 50年
- 平均风的时距
  - 10min

15

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## 标准高度的规定

- 确定风速标准高度时需要考虑多方面原因
- 我国气象站的风速仪高度大多在8~12m之间
- 美国、加拿大等也采用10m标准风速高度
- 日本采用15m风速高度
- 挪威、巴西为20m
- 我国1970年前采用20m高度

16

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## 平均风速的平均时距

- 塘沽1966年8月28日瞬时风速达到48.7m/s, 10分钟平均风速15m/s, 未成灾
- 1967年7月15日瞬时最大风速37.8m/s, 10分钟平均风速21m/s, 成灾
- 10分钟到1小时平均风速基本稳定, 能保持当时风速的基本特点, 又不至于受到过大瞬时风速的影响。

17

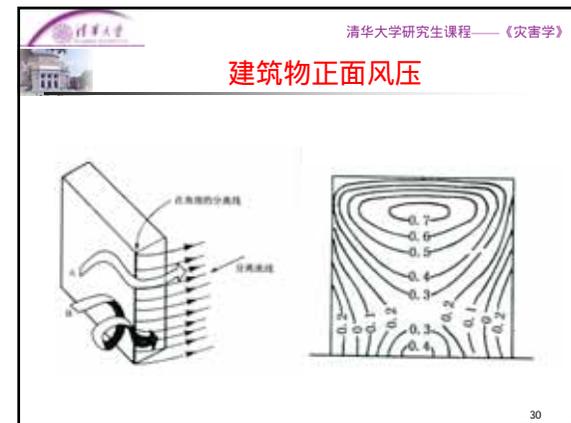
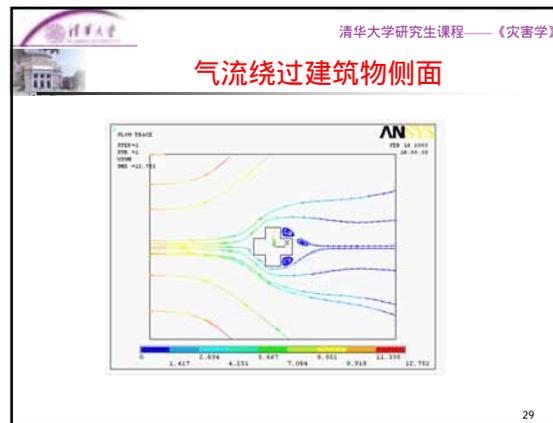
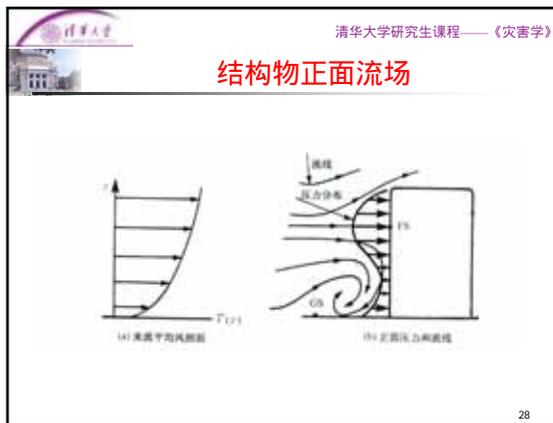
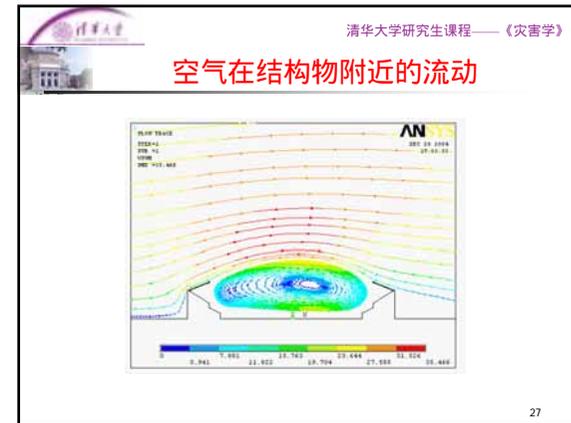
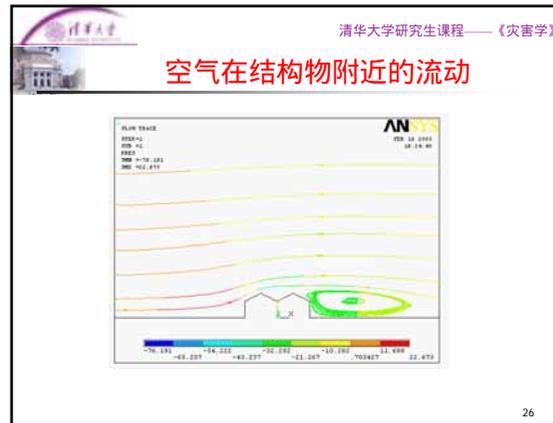
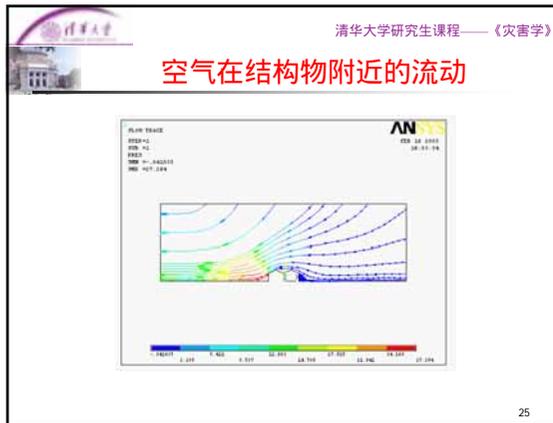
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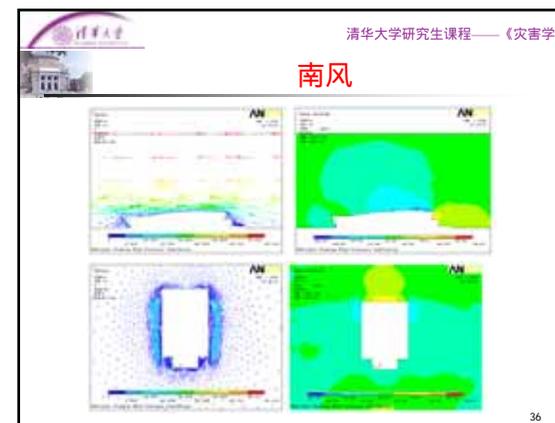
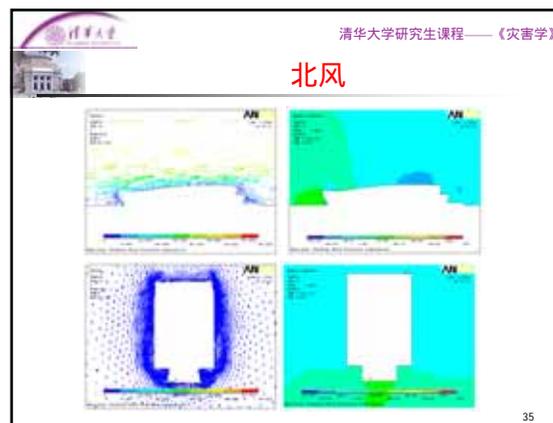
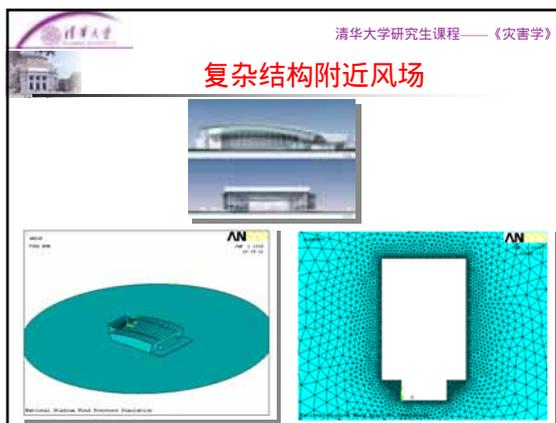
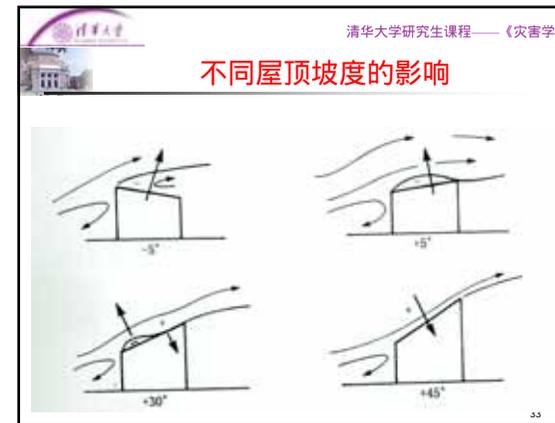
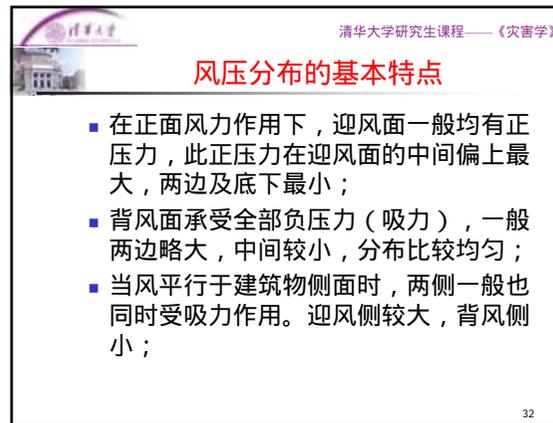
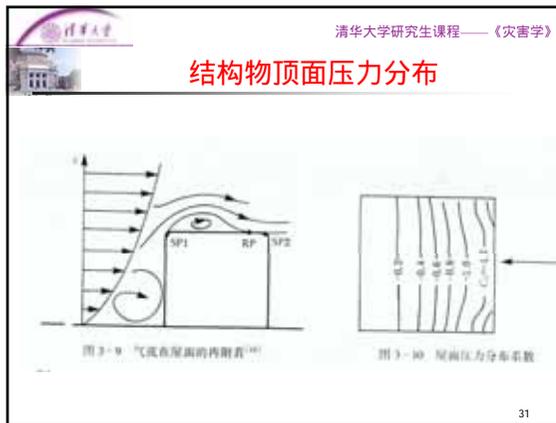
## 不同国家平均风速的规定

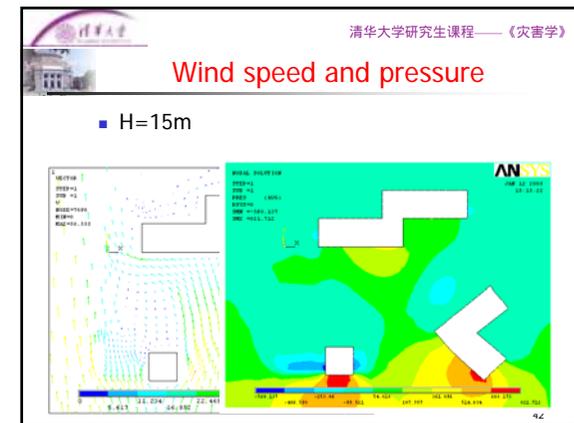
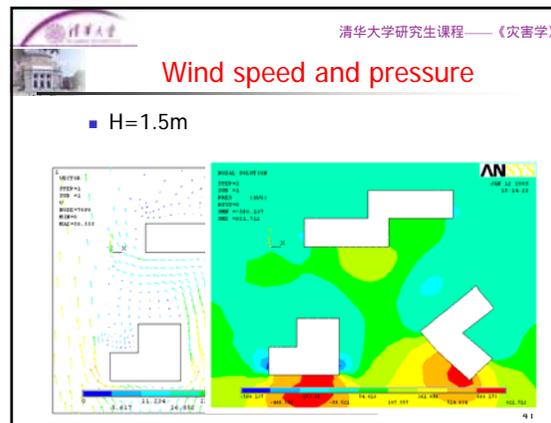
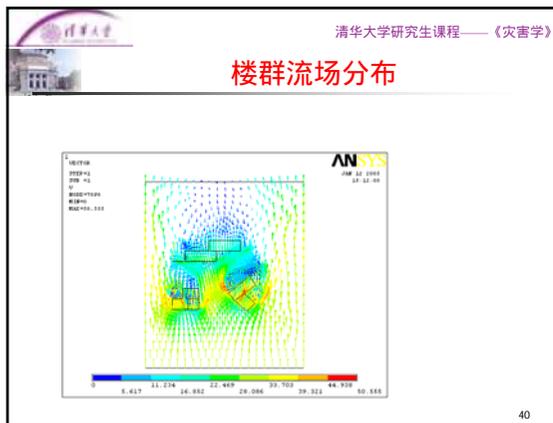
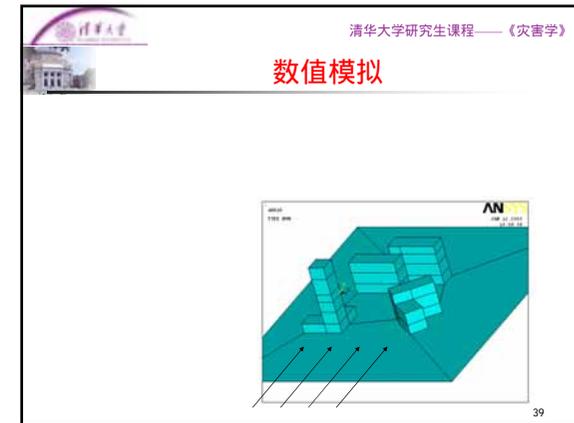
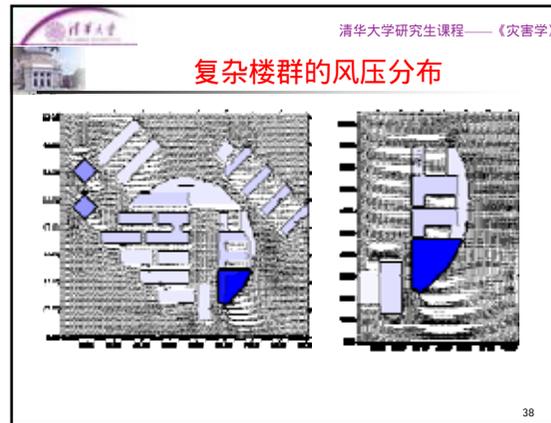
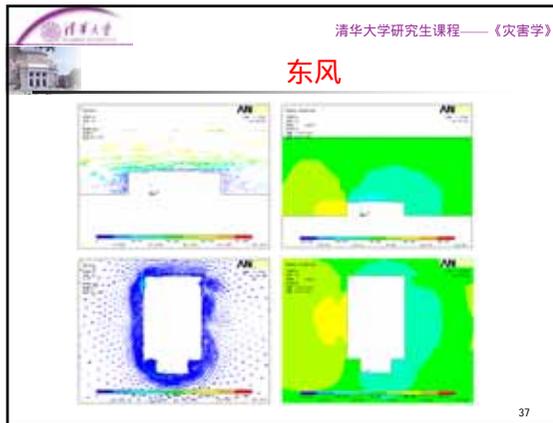
- 日本采用瞬时最大风速
- 美国采用 $t=3000/v$ , 在半分钟到一个小时之间
- 英国、澳大利亚为3秒钟
- 加拿大为1个小时
- 丹麦为10分钟

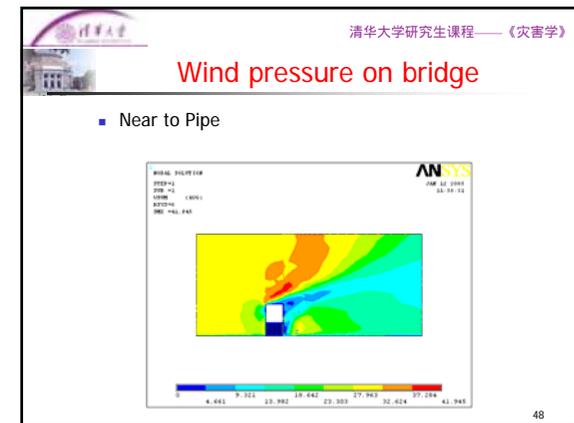
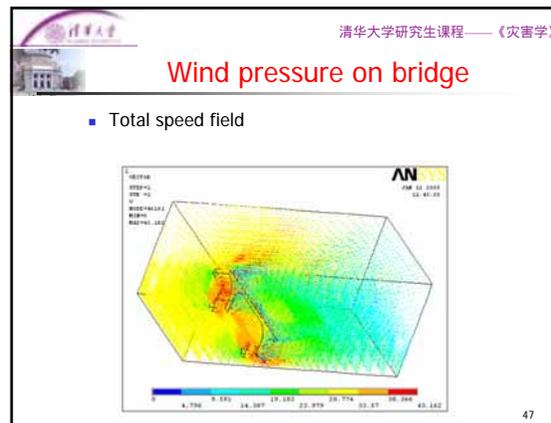
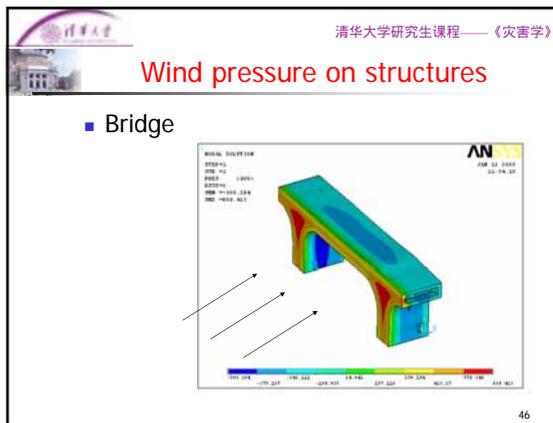
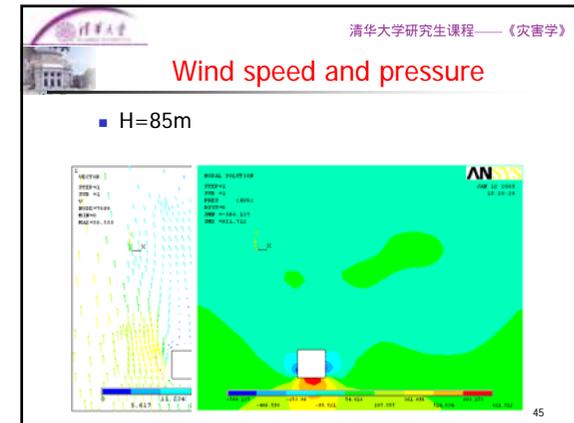
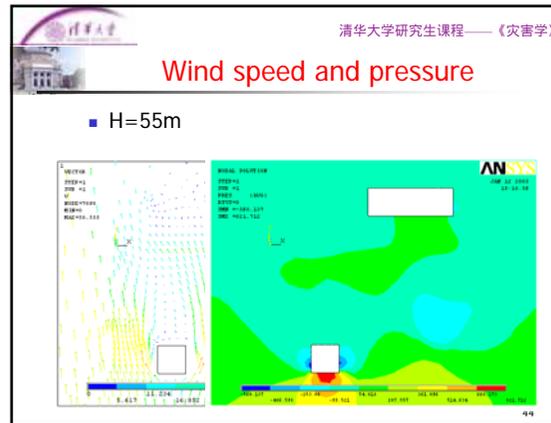
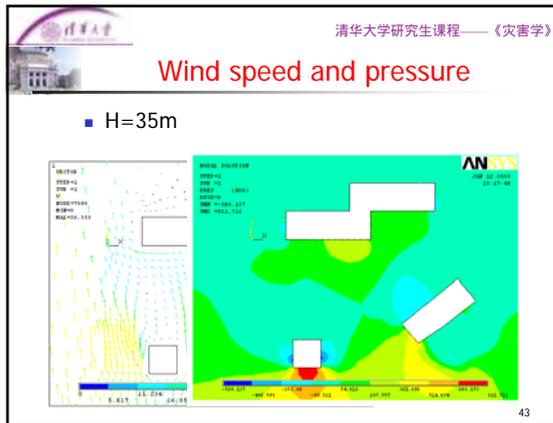
18

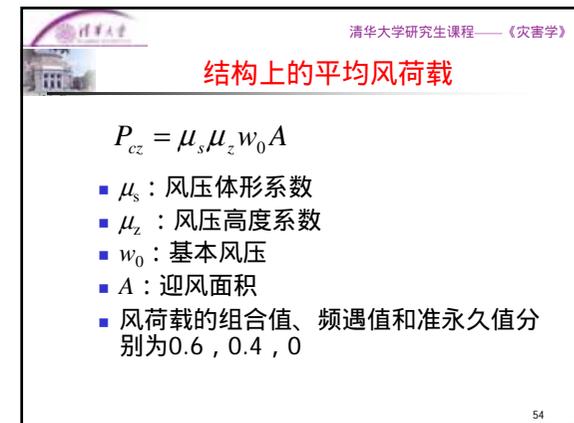
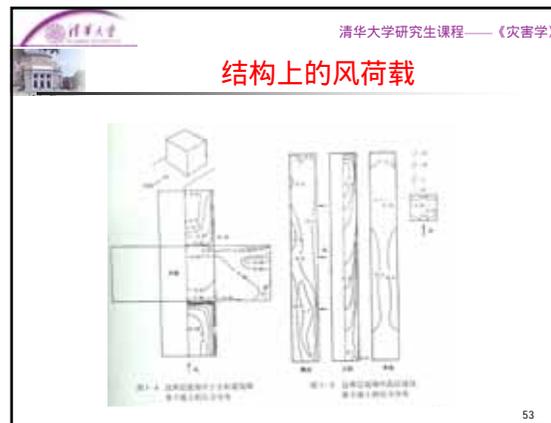
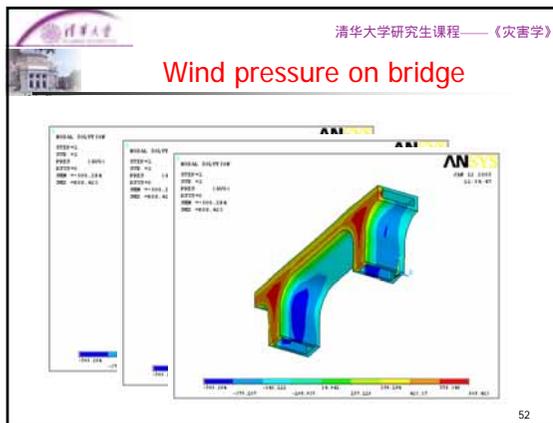
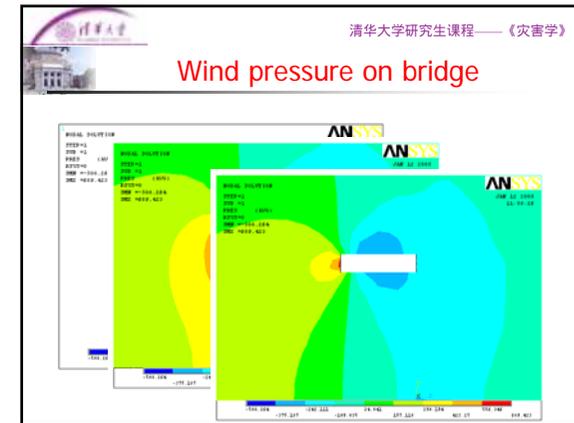
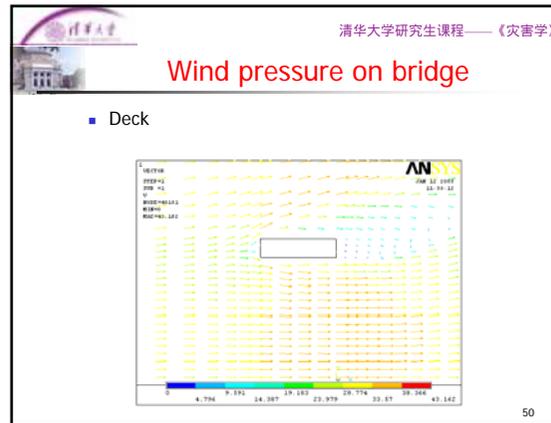
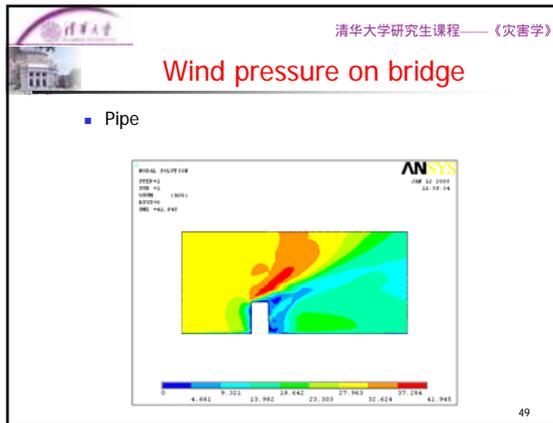












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### 规范规定的风压高度系数计算公式

$$\mu_z = \begin{cases} 1.17 \left(\frac{z}{5}\right)^{0.24} & \text{A} \\ 1.00 \left(\frac{z}{10}\right)^{0.32} & \text{B} \\ 0.74 \left(\frac{z}{15}\right)^{0.44} & \text{C} \\ 0.62 \left(\frac{z}{30}\right)^{0.60} & \text{D} \end{cases}$$

55

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### 风压高度变化系数

$$\frac{\bar{v}(z)}{v_b} = \left(\frac{z}{z_b}\right)^\alpha$$

粗糙度类别	z	z=5m	z=10m	z=15m	z=20m
A	5	1.00	1.00	1.00	1.00
A	10	1.17	1.17	1.17	1.17
A	15	1.25	1.25	1.25	1.25
A	20	1.30	1.30	1.30	1.30
B	5	1.00	1.00	1.00	1.00
B	10	1.04	1.04	1.04	1.04
B	15	1.08	1.08	1.08	1.08
B	20	1.11	1.11	1.11	1.11
C	5	0.74	0.74	0.74	0.74
C	10	0.78	0.78	0.78	0.78
C	15	0.81	0.81	0.81	0.81
C	20	0.83	0.83	0.83	0.83
D	5	0.62	0.62	0.62	0.62
D	10	0.65	0.65	0.65	0.65
D	15	0.67	0.67	0.67	0.67
D	20	0.69	0.69	0.69	0.69

56

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### 非标准场地的风压修正

$$\eta_B = \left[ 1 + k \operatorname{tg} \alpha \left( 1 - \frac{z}{2.5H} \right) \right]^2$$

式中  $\operatorname{tg} \alpha$ —山峰或山坡在迎风面一侧的坡度；当  $\operatorname{tg} \alpha > 0.3$  时，取  $\operatorname{tg} \alpha = 0.3$ ；  
 $k$ —系数，对山峰取 3.2，对山坡取 1.4；  
 $H$ —山顶或山坡全高(m)；  
 $z$ —建筑物计算位置离建筑物地面的高度，m；当  $z > 2.5H$  时，取  $z = 2.5H$ 。

57

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### 非标准场地的风压修正

- 山间盆地、谷地等闭塞地形，修正系数取 0.75~0.85
- 对于与风向一致的谷口、山口，修正系数取 1.2~1.5

7.2.3 对于远海海面和海岛的建筑物或构筑物，风压高度变化系数可按 A 类粗糙度类别，由表 7.2.1 确定外，还应考虑表 7.2.3 中给出的修正系数。

表 7.2.3 远海海面和海岛的修正系数  $\eta$

距海岸距离(km)	$\eta$
< 40	1.0
40~60	1.0~1.1
60~100	1.1~1.2

58

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### 结构物体系数

59

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### 结构物体系数

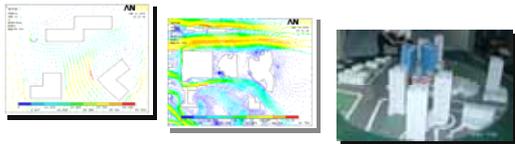
迎风面迎风角 $\alpha$	$\mu_s$	$\mu_{s1}$	$\mu_{s2}$	计算方法
$\alpha = 0^\circ$	0.8	0.8	0.5	中间值插值法计算
$0^\circ < \alpha < 30^\circ$	0.8	0.8	0.7	插值计算
$30^\circ < \alpha < 60^\circ$	1.2	1.0	0.8	A 类为尖顶凸体高度
$60^\circ < \alpha < 90^\circ$	1.5	0.8	0.7	体高度

60

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### 多个建筑物

- 在风压体形系数上乘以相应的增大系数以考虑建筑物之间的相互影响；
- 必要情况下应通过风洞试验加以确定



61

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### 维护构件

- 正压区，按一般体形系数取用
- 负压区
  - 对墙面，取-1.0
  - 对墙角边，取-1.8
  - 对屋面局部部位（周围和屋面坡度大于10度的屋脊部位），取-2.2
  - 对檐口、雨篷、遮阳板等突出构件，取-2.0
- 局部作用宽度为房屋宽度的0.1或者房屋平均高度的0.4，取其小者，但不小于1.5m

62

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### 建筑物的内表面

- 根据外表面的风压情况取为0.2或者-0.2

63