Lecture 1

Presentation of Chinese Codes: Safety Concept, Material Resistances, Loads Combinations

Thei

Member of VTC Group
VTC 機構成員

Contents

1. Design Philosophy
   - Aim of design
   - Limit state design
   - Material resistance
   - Design situation
2. Design actions based on GB50009-2012
   - Types of loading
   - Load combination

DESIGN PHILOSOPHY

Introduction

- The basic design principles for infra-structures and buildings in China are specified in the "*Unified Standard for Reliability Design of Engineering Structures* (GB 50153-2008)".
- The code was drawn up to suit the needs for design of structures, and to conform with the requirements for the safety, serviceability and the economy, rationality of structures.

- GB 50153-2008. Unified standard for reliability design of engineering structures
- GB 50009-2012. Load code for the design of building structures
- GB 50010-2010. Code for design of concrete structures
- GB 50017-2003. Code for design of steel structures
- GB 50011-2010. Code for seismic design of building
- JGJ 3-2010. Technical specification for concrete structures of tall building
- JGJ 138-2001. Technical specification for steel reinforced concrete composite structures

Aims of design

- To ensure that with an acceptable level of probability a structure will, during its intended design working life, perform satisfactorily.
- A structure should:
  - sustain all loads and deformations likely to occur during construction and use;
  - remain fit for the purpose of its intended use;
  - have adequate durability for its environment;
  - have adequate structural resistance for the required fire resistance period; and
  - have resistance to the effects of accidental or deliberate misuse such that it will not be damaged to an extent that is dis-proportionate to the original cause.

Limit state

- The code of practice uses the **limit state design method**.
- A limit state can be defined as the state beyond which the structure no longer fulfils the relevant design criteria.
- A structure designed by the limit state method will have acceptable probabilities that they will not reach a limit state.

Ultimate limit states (ULS) *concern the safety and stability of the whole or part of the structure at ultimate loading conditions.*

Serviceability limit state (SLS) *correspond to limits beyond which the whole or part of the structure becomes unserviceable under working loads.*

Design situations

- Design of structures can be classified into either one of the following *Design Situations*:

	Design situation	Description	Limit state
1	Persistent design situation	Normal conditions	ULS and SLS
2	Transient design situation	Temporary conditions (construction/maintenance)	ULS and/or SLS
3	Accidental design situation	Abnormal conditions (fire/explosion/collision)	ULS
4	Seismic design situation	Buildings located in seismic active zone	ULS and/or SLS

Safety class

- Buildings and structures are classified into three types in according to the consequence when damage occurred.
- The design load effects will be adjusted depending on the safety class.

Table A.1.1 Safety class of buildings and structures

Safety class	Consequence	Examples
1	Very high consequence for loss of life, economy, or society; high environmental impact	Large-scale public housing
2	High consequence for loss of life, economy, or society; relatively high environmental impact	Residential buildings, office buildings, etc.
3	Low consequence for loss of life, economy, or society; small or negligible environmental impact	Storage buildings

Design reference period

- A **50 years** design reference period was adopted for normal buildings.

Table A.1.3 Design reference year of buildings and structures

Type	Design reference period (year)	Example
1	5	Temporary structures
2	25	Replaceable structural components
3	**50**	Normal buildings and structures
4	100	Special structures, landmarks

(GB50010-2010 Clause 4.1)

Material resistance - Concrete

- The **characteristic strength (f_{ck})** of concrete is that value of the cube strength at 28 days below which 5% of all compressive test results would be expected to fall. The characteristic strengths of concrete is summarized in Table 4.1.3-1
- The design compressive and tensile strengths of concrete is summarised in Tables 4.1.4-1 and 4.1.4-2, respectively.
- The elastic modulus shall be obtained in Table 4.1.5.

Table 4.1.3-1 & 4.1.4-1 Characteristic strength and design compressive strength of concrete (N/mm²)

Strength	Concrete grade													
	C15	C20	C25	C30	C35	C40	C45	C50	C55	C60	C65	C70	C75	C80
f_{ck}	10.0	13.4	16.7	20.1	23.4	26.8	29.6	32.4	35.5	38.5	41.5	44.5	47.4	50.2
f_c	7.2	9.6	11.9	14.3	16.7	19.1	21.1	23.1	25.3	27.5	29.7	31.8	33.8	35.9

*Concrete grade should not be less than C20 for RC components

**Concrete grade should not be less than C25 for rebars with design strength beyond 400 MPa

Table 4.1.4-2 Design Tensile strength of concrete (N/mm²)

Strength	Concrete grade													
	C15	C20	C25	C30	C35	C40	C45	C50	C55	C60	C65	C70	C75	C80
f_t	0.91	1.10	1.27	1.43	1.57	1.71	1.80	1.89	1.96	2.04	2.09	2.14	2.18	2.22

Table 4.1.5 Elastic modulus of concrete ($\times 10^4$ N/mm²)

Strength	Concrete grade													
	C15	C20	C25	C30	C35	C40	C45	C50	C55	C60	C65	C70	C75	C80
E_c	2.20	2.55	2.80	3.00	3.15	3.25	3.35	3.45	3.55	3.60	3.65	3.70	3.75	3.80

(GB50010-2010 Clause 4.2)

Material resistance - Reinforcement

- HRB400, HRB500, HRBF400 and HRBF500 shall be adopted as the longitudinal reinforcement for beam and column.
- HRB400, HRBF400, HPB300, HRB500 and HRBF500 (or HRB335, HRBF335) shall be adopted as stirrup.
- The design tensile and compressive strength can be obtained in Table 4.2.3-1.
- The elastic modulus can be obtained in Table 4.2.5.

Table 4.2.2-1 and 4.2.3-1 Characteristic strength and design strength of steel bar (N/mm^2)

Type of steel bars	Characteristic Strength f_{yk}	Design Tensile strength f_y	Design Compressive strength f_y'
HPB300	300	270	270
HRB335, HRBF335	335	300	300
HRB400, HRBF400, RRB400	400	360	360
HRB500, HRBF500	500	435	410

Table 4.2.5 Elastic modulus of steel bars (× 10^5 N/mm^2)

Type of steel bars	Elastic modulus E_s
HPB300	2.10
HRB355, HRB400, HRB500 HRBF335, HRBF400, HRBF500 RRB400	2.00

Table A.0.1 Diameter, area and weight of steel bars

Diameter (mm)	Area of groups of steel bars (mm^2)									Weight of a steel bar (kg/m)
	1	2	3	4	5	6	7	8	9	
6	28. 3	57	85	113	142	170	198	226	255	0. 222
8	50. 3	101	151	201	252	302	352	402	453	0. 395
10	78. 5	157	236	314	393	471	550	628	707	0. 617
12	113. 1	226	339	452	565	678	791	904	1017	0. 888
14	153. 9	308	461	615	769	923	1077	1231	1385	1. 21
16	201. 1	402	603	804	1005	1206	1407	1608	1809	1. 58
18	254. 5	509	763	1017	1272	1527	1781	2036	2290	2. 00(2. 11)
20	314. 2	628	942	1256	1570	1884	2199	2513	2827	2. 47
22	380. 1	760	1140	1520	1900	2281	2661	3041	3421	2. 98
25	490. 9	982	1473	1964	2454	2945	3436	3927	4418	3. 85(4. 10)
28	615. 8	1232	1847	2463	3079	3695	4310	4926	5542	4. 83
32	804. 2	1609	2413	3217	4021	4826	5630	6434	7238	6. 31(6. 65)
36	1017. 9	2036	3054	4072	5089	6107	7125	8143	9161	7. 99
40	1256. 6	2513	3770	5027	6283	7540	8796	10053	11310	9. 87(10. 34)
50	1963. 5	3928	5892	7856	9820	11784	13748	15712	17676	15. 42(16. 28)

DESIGN ACTIONS BASED ON GB50009-2012

GB50009-2012

- Most of the structural actions (loading) is summarised in “*Load code for the design of building structures* (GB50009-2012)”.
- Earthquake load is covered in GB50011-2010.

UDC

中华人民共和国国家标准 GB

P GB 50009－2012

建筑结构荷载规范

Load code for the design of building structures

2012－05－28 发布 2012－10－01 实施

中华人民共和国住房和城乡建设部
中华人民共和国国家质量监督检验检疫总局 联合发布

Classification of loads

Permanent Loads

- The variation of load, which is compared with the mean value, is not significant throughout its service period.
- Self-weight of structural members, earth pressure, water pressure and pre-stressing force, etc.

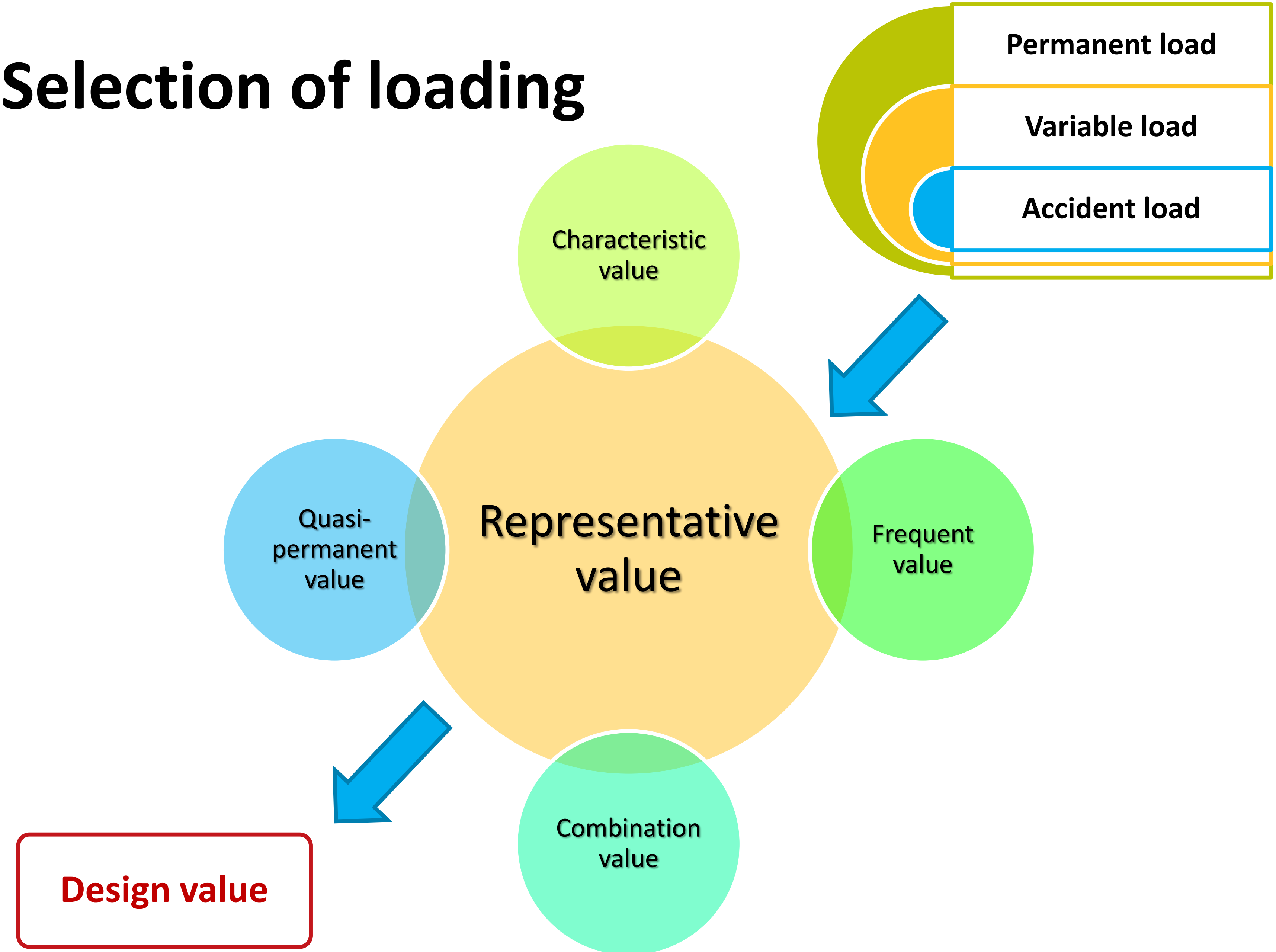
Variable Loads

- The value of load is varied with time.
- Live load, crane load, wind load, snow load, etc.

Accidental Loads

- The load is not occurred definitely. Once it is occurred, the load is with a significant value and its duration is usually short.
- Explosive force, collision force, seismic action, etc.

Selection of loading



Representative value

- **Representative value** = measuring values of a load that are adopted for the checking of the limit states in design.
- Different representative value shall be adopted for different loads in the design of building.
  - **Permanent load**: Characteristic value (Clause 3.1.2)
  - **Variable load**: Characteristic value; Combination value; Frequent value; Quasi-permanent value — **Depends on the combination**
  - **Accidental load**: Determinate in accordance to the distinguish features of service for the building.

Characteristic value of load

- **Characteristic load** (Q_k) = the characteristic value for the *statistical distribution* of the maximum load in the design reference period, such as mean-value, mode, mid-value or certain fractile.

Combination values of load

- **Combination value** = the values of variable loads after combination, that their transcendental probability in the design reference period can be tended toward *identical with the corresponding probability for the load effect of the appearance of single load alone*.
    - This is for the situations where the floor is subjected to more than one type of variable loads.
    - The value shall be the characteristic values multiplied by the coefficients for combination value of loads ψ_c.

$$\text{Combination value} = \psi_c Q_k$$

Frequent values of load

- **Frequent value** = the value of variable load in the design reference period, that the transcendental total time is in small ratio of stipulated time, or the transcendental frequency is the stipulated frequency.
  - The value shall be the characteristic value multiplied by the coefficient for frequent value of load ψ_f.

$$\text{Frequent value} = \psi_f Q_k$$

Quasi-permanent values of load

- **Quasi-permanent value** = the value of variable load that the transcendental total time is about one-half of the design reference period.
  - This aims as reflecting the time-varying nature of load effects throughout the design period.
  - The value shall be the characteristic value multiplied by the coefficient for quasi-permanent value of load ψ_q.

$$\text{Quasi} - \text{permanent value} = \psi_q Q_k$$

Design value

- For structural members designed for a limit state, the ***design loads*** should be used in the calculation rather the mean values or the characteristic values of loading.
- The design load are computed as

$$Design\ Load = Representative\ Load\ \times (\gamma_G \text{ or } \gamma_Q)$$

Permanent load, variable load, or accident load

Partial safety factors for loading

Permanent load

(Clause 4)

- The characteristic value of permanent load can be computed in according to the following situations:
  - For self-weight of structures, it can be determined by multiplying the dimensions of structural member and the unit weight of material.
  - For structural members with nonuniform self-weight, the upper or lower characteristic value of self-weight shall be taken according to unfavourable situations.
  - Non-moveable partition may be considered as permanent load, while moveable partition may be considered as variable load.
  - The unit weight of materials can be referred to the Appendix A of the Code.

Steel:	78.5 kN/m^3
RC:	22.0 – 24.0 kN/m^3

Variable load

(Clause 5)

- Types of variable loads:
  - Live load on floor and roof
  - Crane load, snow load
  - Wind load
- Classification of live loads
  1. Uniform live loads on floors in civil buildings
  2. Live loads on floors in industrial buildings
  3. Live loads on roofs
  4. Ash load on roofing
  5. Construction and maintenance loads, and horizontal load on railings

Live loads on floor in civil building (Clause 5.1.1)

- The characteristic value and the coefficients of uniform live loads shall be taken according to Table 5.1.1 in Clause 5.1.1.

Table 5.1.1 The characteristic values and the coefficients for combination value, frequent value and quasi-permanent value of uniform live loads in civil buildings (GB50009-2012)

Totally 13 items

Item	Type	Characteristic value (kN/m^2)	Coefficient for combination value ψ_c	Coefficient for frequent value ψ_f	Coefficient for quasi-permanent value ψ_q
1	(1) Residential, hotel, office	2.0	0.7	0.5	0.4
	(2) Laboratory	2.0	0.7	0.6	0.5
2	Classroom, canteen	2.5	0.7	0.6	0.5
3	(1) Hall, theatre	3.0	0.7	0.5	0.3
	(2) Laundry	3.0	0.7	0.6	0.5

Live loads reduction coefficients (Clause 5.1.2)

- For design of *beams*, *walls*, *columns* and *foundations*, the characteristic values of live load shall be multiplied by the following specified reduction coefficients.

1. *Design of beams*:
   1. **Item No. 1(1)**: for beams with tributary area exceed 25 m^2, 0.9 shall be taken.
   2. **Item No. 1(2) to 7**: for beams with tributary area exceed 50 m^2, 0.9 shall be taken.
   3. **Item No. 8**: for secondary beams in one-way slab or composite slab with steel decking, 0.8 shall be taken; for primary beams in one-way slab, 0.6 shall be taken; for beams in two-way slab, 0.8 shall be taken.
   4. **Item No. 9 to 13**: the reduction coefficients, which belong in same kind of buildings, shall be adopted.

(Clause 5.1.2)

2. Design of walls, columns and foundations:

1. **Item No. 1(1)**: in according to Table 5.1.2 in Clause 5.1.2.
2. **Item No. 1(2) to 7**: refer to the reduction coefficients for floor beams.
3. **Item No. 8**: for one-way slab, 0.5 shall be taken; for two-way slab and flat slab, 0.8 shall be taken.
4. **Item No. 9 to 13**: the reduction coefficients, which belong in same kind of buildings, shall be adopted.

Table 5.1.2 Reduction coefficient of live load according to the number of storeys in a building (GB50009-2012)

Number of storeys above the calculated members	**1**	**2 - 3**	**4 - 5**	**6 - 8**	**9 - 20**	**> 20**
Reduction coefficients of the total live loads on each floor	1.00 (0.90)	0.85	0.70	0.65	0.6	0.55

The value in brackets is adopted when the tributary area of the beam is larger than 25 m^2.

Illustrative example

Usage: residential building

Thickness: 150 mm
Finishes: 30 mm
Partition (non-movable): 2 kPa
Floor load: 2 kPa

Concrete density: 24 kN/m^3

Permanent load:

Characteristic value = 24 x 0.15 + 24 x 0.03 + 2 = 6.32 kPa

Variable load:

Characteristic value	=	2.0 kPa
Combination value = 2 x 0.7	=	1.4 kPa
Frequent value = 2 x 0.5	=	1.0 kPa
Quasi-permanent value = 2 x 0.4	=	0.8 kPa

Combination of loads

Load combinations for ULS

- Fundamental combination
- Accidental combination

Load combinations for SLS

- Characteristic combination
- Frequent combination
- Quasi-permanent combination

1. The most unfavourable combination of loads shall be taken into account in the design.
2. For seismic design combination, refer to GB 50011-2010

(Clause 3.1.5 and 3.1.6)

Ultimate limit state					
Combination	Representative value of permanent load	Representative value of variable load			
	Characteristic value	Characteristic value	Combination value	Frequent value	Quasi-permanent value
Fundamental	√	√	√		
Accidental	√	√		√	√

Serviceability limit state					
Combination	Representative value of permanent load	Representative value of variable load			
	Characteristic value	Characteristic value	Combination value	Frequent value	Quasi-permanent value
Characteristic	√	√	√		
Frequent	√	√		√	
Quasi-permanent	√	√			√

Combination of loads for ULS (Clause 3.2.2)

- For ULS, the combination of loads shall be carried out with
  1. the ***fundamental combination*** or
  2. the ***accidental combination***
- The following design expression shall be adopted:

$$\underbrace{\gamma_0 S_d}_{\text{Design load}} \leq R_d\left(\frac{f_k}{\gamma_M}\ldots\right)$$

Design load

Table A.1.7 in Appendix A, GB50153-2008

Importance coefficient	Persistent and transient design situations			Accidental and earthquake design situation
	Safety class			
	1	2	3	
γ_0	1.1	1.0	0.9	1.0

where

γ_0 is the importance coefficient of structure;
S_d is the design value of combination of load effects;
R_d is the design value of the resistance of structural members.

Fundamental combination

(Clause 3.2.3)

- For the fundamental combination, the design value S_d shall be taken by the most unfavourable value from the following cases:
  1. The combination is controlled by the *variable load effects*:

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \gamma_{Q_1} \gamma_{L_1} S_{Q_1 k} + \sum_{i=2}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

Accompany variable load

Leading/controlling variable load

Adjustment factor for design reference period

  2. The combination is controlled by the *permanent load effects*:

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \sum_{i=1}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

γ_{Gj} is the partial safety factor of permanent load of number *j*

γ_{Qi} is the partial safety factor of variable load of number *i*; where γ_{Qi} is for the controlling variable load Q_1

γ_{Li} is the adjustment factor of variable load of number *i* with the consideration of design reference period

S_{Gjk} is the characteristic value of permanent load G_{jk} of number *j*

S_{Qik} is the characteristic value of variable load Q_{ik} of number *i*; where S_{Q1k} denotes the controlling one among all variable loads

ψ_{ci} is the coefficients of combination values of variable loads Q_i

m is the number of permanent loads participated in the combinations

n is the number of variable loads participated in the combinations

Partial safety factor

(Clause 3.2.4)

- Partial safety factors of *permanent load* γ_G and ***variable load*** γ_Q are summarised as follows:

	Unfavourable		Favourable
	Variable load controlled	Permanent load controlled	
γ_G	**1.2**	**1.35**	**≤ 1.0**
γ_Q	**1.4**		**0.0**

Remarks: For the characteristic value of variable load is greater than 4 kN/m^2 for floor structure of industrial building, **1.3** shall be taken.

Adjustment factor

(Clause 3.2.5)

- Adjustment factor for variable loads γ_L may be used to modified the design reference period.
- The values can be obtained from Table 3.2.5.

Design reference period (year)	**5**	**50**	**100**
γ_L	0.9	1.0	1.1

Remarks: Intermediate value may be used

- For snow load and wind load, the return period should be selected as the design reference period.

Remarks

- For variable load controlled combination,

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \gamma_{Q_1} \gamma_{L_1} S_{Q_1 k} + \sum_{i=2}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

Dead + ***single*** independent variable load

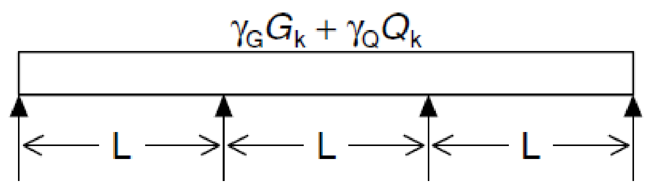
$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \gamma_{Q_1} \gamma_{L_1} S_{Q_1 k}$$

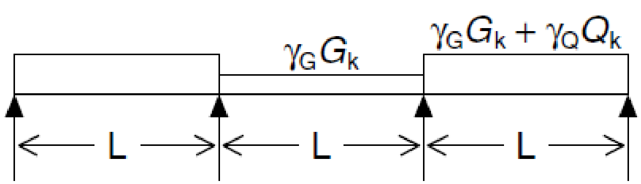
Dead + ***two*** independent variable loads

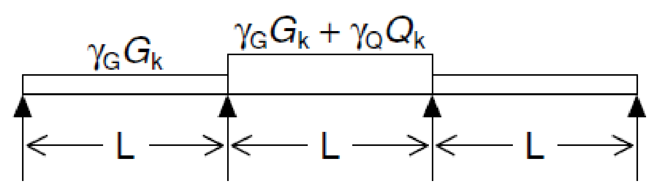
$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \gamma_{Q_1} \gamma_{L_1} S_{Q_1 k} + \gamma_{Q_2} \gamma_{L_2} \psi_{c_2} S_{Q_2 k}$$

Remarks

- Favourable and un-favourable actions







Accidental combination

(Clause 3.2.6)

- For the accidental combination, the design value S_d shall be taken as:
  1. For ULS design

$$S_d = \sum_{j=1}^{m} S_{G_j k} + S_{A_d} + \psi_{f_1} S_{Q_1 k} + \sum_{i=2}^{n} \psi_{q_i} S_{Q_i k}$$

  2. For overall stability check after accidental event

$$S_d = \sum_{j=1}^{m} S_{G_j k} + \psi_{f_1} S_{Q_1 k} + \sum_{i=2}^{n} \psi_{q_i} S_{Q_i k}$$

where

S_{Ad}	is the characteristic value of accidental load A_d;
ψ_{fi}	is the coefficients of frequent values of variable loads Q_i.
ψ_{qi}	is the coefficients of quasi-permanent values of variable loads Q_i.

Combination of loads for SLS (Clause 3.2.7)

- For SLS, the load effects shall be determined based on
  1. the ***characteristic combination***,
  2. the ***frequent combination*** or
  3. the ***quasi-permanent combination***.
- The design shall be carried on according to the design expression

$$S_d \leq C$$

where

C is stipulated limiting values, which denote the structures or the structural members reaching the requirements of normal service, such as the limiting values of deformation, crack, vibration amplitude, acceleration, stress, etc.

- For characteristic combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + S_{Q_1 k} + \sum_{i=2}^{n} \psi_{c_i} S_{Q_i k}$$

- For frequent combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + \psi_{f_1} S_{Q_1 k} + \sum_{i=2}^{n} \psi_{q_i} S_{Q_i k}$$

- For quasi-permanent combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + \sum_{i=1}^{n} \psi_{q_i} S_{Q_i k}$$

Example 1

Determine the maximum bending moment and shear force of the following members based on GB50009-2012.

<u>Given information</u>

Permanent load, $S_{G_1k} = 10 \text{ kN/m}$

Variable load, $S_{Q_1k} = 6 \text{ kN/m}$ (hotel, characteristic value)

Design reference period of 50 years

Safety class 2

Solution

Ultimate limit state: Consider fundamental combination

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \gamma_{Q_1} \gamma_{L_1} S_{Q_1 k} + \sum_{i=2}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

Controlled by variable load

$$\gamma_G = 1.2, \gamma_Q = 1.4$$

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \sum_{i=1}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

Controlled by permanent load

$$\gamma_G = 1.35, \gamma_Q = 1.4$$

For hotel usage → Coefficient of combination value $\psi_c = 0.7$

Design reference period of 50 years → Adjustment factor for design reference period $\gamma_L = 1.0$

Safety class 2 → Importance coefficient $\gamma_0 = 1.0$

Variable load controlled

$$S_d = \gamma_{G_1} S_{G_1k} + \gamma_{Q_1}\gamma_{L_1} S_{Q_1k} = 1.2 \times 10 + 1.4 \times 1.0 \times 6 = 20.4 \text{ kN/m}$$

Permanent load controlled

$$S_d = \gamma_{G_1} S_{G_1k} + \gamma_{Q_i}\gamma_{L_i}\psi_{c_i} S_{Q_ik} = 1.35 \times 10 + 1.4 \times 1.0 \times 0.7 \times 6 = 19.4 \text{ kN/m}$$

Design load $\gamma_0 S_d = 1.0 \times S_d = S_d$

$$M_{max} = \frac{1}{8} S_d L^2 = \frac{1}{8}(20.4)\,(8)^2 = 163.2 \text{ kNm}$$

$$V_{max} = \frac{1}{2} S_d L = \frac{1}{2}(20.4)\,(8) = 81.6 \text{ kN}$$

Serviceability limit state: Consider all three combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + S_{Q_1 k} + \sum_{i=2}^{n} \psi_{c_i} S_{Q_i k}$$

Characteristic combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + \psi_{f_1} S_{Q_1 k} + \sum_{i=2}^{n} \psi_{q_i} S_{Q_i k}$$

Frequent combination

$$S_d = \sum_{j=1}^{m} S_{G_j k} + \sum_{i=1}^{n} \psi_{q_i} S_{Q_i k}$$

Quasi-permanent combination

For hotel usage →

Coefficient of combination value $\psi_c = 0.7$

Coefficient of frequent value $\psi_f = 0.5$

Coefficient of quasi-permanent value $\psi_q = 0.4$

Characteristic combination

$$S_d = S_{G_j k} + S_{Q_1 k} = 10 + 6 = 16 \text{ kN/m}$$

Frequent combination

$$S_d = S_{G_j k} + \psi_{f_1} S_{Q_1 k} = 10 + 0.5 \times 6 = 13 \text{ kN/m}$$

Quasi-permanent combination

$$S_d = S_{G_j k} + \psi_{q_i} S_{Q_i k} = 10 + 0.4 \times 6 = 12.4 \text{ kN/m}$$

$$S_d \leq C$$

Snow load

(Clause 7.1)

- The characteristic value of wind load is determined in accordance with the following equation:

$$s_k = \mu_r s_0$$

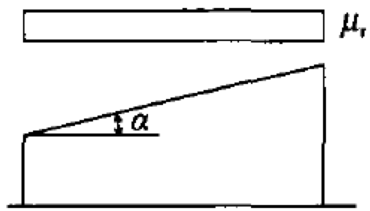
where

s_k	is the characteristic value of snow load (kN/m^2)
μ_r	is the roof snow distribution factor (Table 7.2.1)
s_0	is the reference snow pressure (kN/m^2)

Roof snow distribution factor – type 1 & 2

Type 1: Single pitched roof

(Refer to Table 7.2.1)

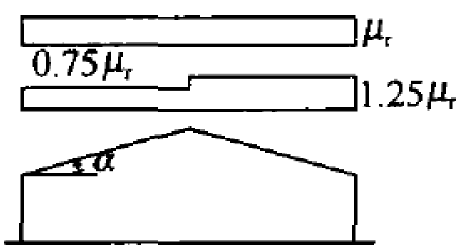


α	≤25°	30°	35°	40°	45°	50°	55°	≥60°
μ_r	1.0	0.85	0.7	0.55	0.4	0.25	0.1	0

Type 2: Double pitched roof

Evenly distributed:

Unevenly distributed:



Note: μ_r of type 2 will be the same value of type 1

(Appendix E.5)

Table E.5 Snow pressure during a 50-year mean recurrence interval of nation-wide cities and towns

Provincial, municipal names	City, town names	Height above sea level (m)	Snow pressure (kN/m²)		
			R = 10	R = 50	R = 100
Beijing		54.0	0.25	0.40	0.45
Tianjin	Tainjinshi	3.3	0.25	0.40	0.45
Shanghai		2.8	0.10	0.20	0.25
Guangdong	Guangzhoushi	6.6	0.00	0.00	0.00
	Shenzhenshi	18.2	0.00	0.00	0.00

The coefficients for snow pressure are as follows:

Coefficient of combination value ψ_c	Coefficient of frequent value ψ_f	Coefficient of quasi-permanent value ψ_q
0.7	0.6	0.5*

* The value for coeff. of quasi-permanent value is region dependent

Wind load

(Clause 8.1)

- The characteristic value of wind load is determined in accordance with the following equations:
  1. Design of principal load-bearing structures

$$w_k = \beta_z \mu_s \mu_z w_0$$

where

w_k	is the characteristic value of wind load (kN/m^2)
β_z	is the dynamic effect factor of wind at a height of z (Clause 8.4)
μ_s	is the shape factor of wind load (Clause 8.3)
μ_z	is the exposure factor for wind pressure (Clause 8.2)
w_0	is the reference wind pressure (kN/m^2)

(Clause 8.1)

- The reference wind pressure w_0 is specified in Appendix E in GB50009-2012.
  - The value is based on the wind with return period of 50 years.
  - The wind pressure shall not be less than 0.3 kN/m^2.

- The coefficients for wind pressure are as follows:

Coefficient of combination value ψ_c	Coefficient of frequent value ψ_f	Coefficient of quasi-permanent value ψ_q
0.6	0.4	0.0

(Appendix E.5)

Table E.5 Wind pressure during a 50-year mean recurrence interval of nation-wide cities and towns

Provincial, municipal names	City, town names	Height above sea level (m)	Wind pressure (kN/m^2)		
			R = 10	R = 50	R = 100
Beijing		54.0	0.30	0.45	0.50
Tianjin	Tainjinshi	3.3	0.30	0.50	0.60
Shanghai		2.8	0.40	0.55	0.60
Guangdong	Guangzhoushi	6.6	0.30	0.50	0.60
	Shenzhenshi	18.2	0.45	0.75	0.90

Exposure factor

(Clause 8.2)

- The value of exposure factor of wind load μ_z is specified in Table 8.2.1 in Clause 8.2.1.
- The terrain roughness is classified into four categories:

Category	Description
A	shore sear surface, islands, sear shores, lake shores and deserts.
B	open fields, village, forests, hills, sparsely-populated towns and city suburbs.
C	urban districts in densely-populated cities.
D	densely-populated cities with high building urban districts.

(Clause 8.2.1)

Table 8.2.1 Exposure factor μ_z for wind pressure (GB50009-2012)

Height above terrain or sea level (m)	Terrain roughness categories			
	A	B	C	D
5	1.09	1.00	0.65	0.51
10	1.28	1.00	0.65	0.51
15	1.42	1.13	0.65	0.51
20	1.52	1.23	0.74	0.51
30	1.67	1.39	0.88	0.51
40	1.79	1.52	1.00	0.60
50	1.89	1.62	1.10	0.69
60	1.97	1.71	1.20	0.77
70	2.05	1.79	1.28	0.84
80	2.12	1.87	1.36	0.91

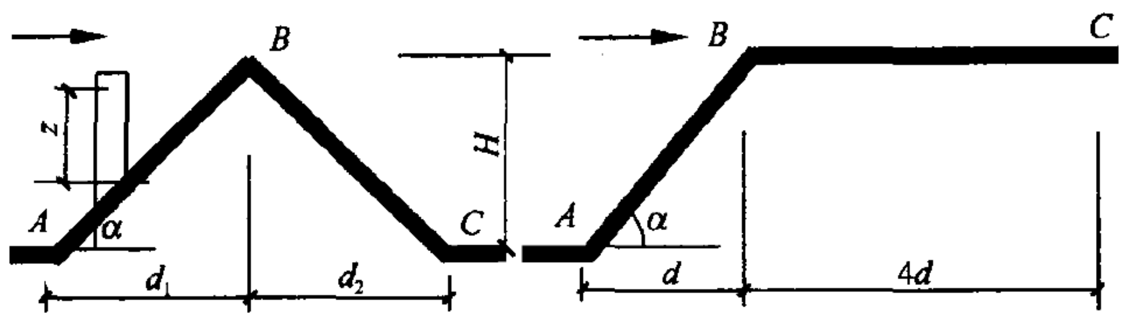
(Clause 8.2.2)

- The coefficients for taking in account for the topography effect is given as

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

where

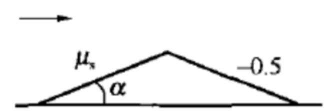
tanα	slope on the windward side of the mountain peak or the mountain slop; when tanα > 0.3, taking tanα = 0.3
κ	coefficients (1) for the mountain peak taking 2.2; (2) for the mountain slope, taking 1.4
H	full height of the mountain peak or the mountain slope (m)
z	height for the calculating position for buildings from the ground in metre; when z > 2.5H, taking z = 2.5H

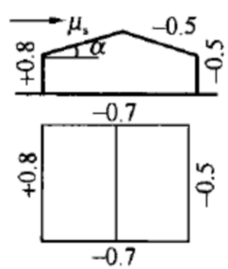


Shape factor

(Clause 8.3)

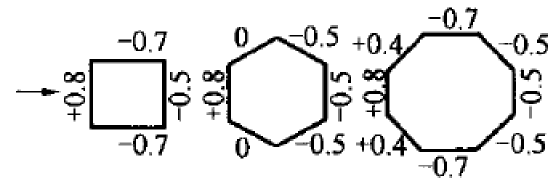
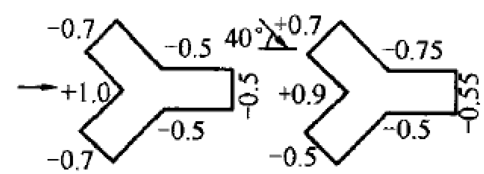
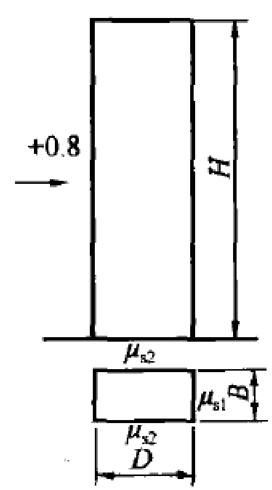
- The value of shape factor of wind load is specified in Table 8.3.1 in GB50009-2012 Clause 8.3.
  - Other references or results from wind tunnel test may be used.

<table>
<tr><th>Item</th><th>Types</th><th>Shape factors</th></tr>
<tr><td>1</td><td>Enclosed double pitched roof on the ground</td><td>

<table><tr><th>α</th><th>μs</th></tr><tr><td>0°</td><td>0.0</td></tr><tr><td>30°</td><td>+0.2</td></tr><tr><td>≥60°</td><td>+0.8</td></tr></table></td></tr>
<tr><td>2</td><td>Enclosed double pinched roof</td><td>

<table><tr><th>α</th><th>μs</th></tr><tr><td>≤15°</td><td>-0.6</td></tr><tr><td>30°</td><td>0.0</td></tr><tr><td>≥60°</td><td>+0.8</td></tr></table></td></tr>
</table>

Totally 39 items

<table>
<tr><th>Item</th><th>Types</th><th>Shape factors</th></tr>
<tr><td>30</td><td>Enclosed typed buildings and structural constructions</td><td>(a) Rectangular / polygonal plan

(b) Y-shape
</td></tr>
<tr><td>31</td><td>Rectangular building whit H > 45 m</td><td>
<table>
<tr><th>D/B</th><th>≤1</th><th>1. 2</th><th>2</th><th>≥4</th></tr>
<tr><td>μ_{s1}</td><td>−0. 6</td><td>−0. 5</td><td>−0. 4</td><td>−0. 3</td></tr>
<tr><td>μ_{s2}</td><td colspan="4">−0. 7</td></tr>
</table></td></tr>
</table>

Dynamic effect of wind

(Clause 8.4)

- The influence of the along wind motion due to fluctuation effects of wind pressure shall be considered for buildings with
  1. height greater than 30m;
  2. height-to-width ratio greater than 1.5; and
  3. fundamental period greater than 0.25 second,
- The random vibration theory shall be used for the calculation of the along wind excitation.
- For common high-rise building, gust factor method shall be adopted.

Dynamic effect factor

(Clause 8.4)

- For common cantilever structures, only the influence of first vibration mode may be considered.
- At level z, the dynamic effect factor is given as

$$\beta_z = 1 + 2gI_{10}B_z\sqrt{1 + R^2}$$

where

g	is the peak factor, taken as 2.5
I_{10}	is the turbulence intensity at z = 10 m, taken as 0.12, 0.14, 0.23 and 0.39 for surface roughness A, B, C and D, respectively
R	resonant response factor for the fluctuation of wind load (next slide)
B_z	background response factor for the fluctuation of wind load (next slide)

(Clause 8.4)

$$R = \sqrt{\frac{\pi}{6\zeta_1}\frac{x_1^2}{(1+x_1^2)^{4/3}}}$$

$$x_1 = \frac{30f_1}{\sqrt{k_w w_0}} > 5$$

$$\text{Period } T_1 = (0.05\sim0.15)n$$

where

f_1	is the fundamental frequency of building (in Hz)
k_w	is the surface roughness adjustment factor, taken as 1.28, 1.0, 0.54 and 0.26 for surface roughness A, B, C and D, respectively
ζ	is the damping ratio; taken as 1% for steel structures and 5% for RC buildings
n	number of storey

$$B_z = kH^{a_1}\rho_x\rho_z\frac{\phi_1(z)}{\mu_z}$$

$$\rho_z = \frac{10\sqrt{H + 60e^{-H/60} - 60}}{H} \qquad \rho_x = \frac{10\sqrt{B + 50e^{-B/50} - 50}}{B}$$

where

ϕ_1	is the mode shape for mode 1 (Appendix G)
H	is the total height, should not greater than 300 m, 350 m, 450 m and 550 m for surface roughness A, B, C and D, respectively
ρ_x	is the wind fluctuation factor along horizontal direction
ρ_z	is the wind fluctuation factor along vertical direction
k, a_1	is coefficients in Table 8.4.5-1
B	is the width of building (m) ≤ 2H

(Clause 8.4)

Table 8.4.5-1 Coefficient k and a_1

Roughness		A	B	C	D
Tall building	k	0.944	0.670	0.295	0.112
	a_1	0.155	0.187	0.261	0.346
Super tall building	k	1.276	0.910	0.404	0.155
	a_1	0.186	0.218	0.292	0.376

(Appendix G)

Table G.0.3 Mode shape for tall building

Relative height	Mode shape			
z/H	1	2	3	4
0.1	0.02	-0.09	0.22	-0.38
0.2	0.08	-0.30	0.58	-0.73
0.3	0.17	-0.50	0.70	-0.40
0.4	0.27	-0.68	0.46	0.33
0.5	0.38	-0.63	-0.03	0.68
0.6	0.45	-0.48	-0.49	0.29
0.7	0.67	-0.18	-0.63	-0.47
0.8	0.74	0.17	-0.34	-0.62
0.9	0.86	0.58	0.27	-0.02
1.0	1.00	1.00	1.00	1.00

Across-wind motion

(Clause 8.6)

- For super tall buildings or slender buildings with round section, the checking of the across-wind motion (vortex shedding) shall be carried out.
- The design situations depends on the value of Reynolds number

$$R_e = 69000vD$$

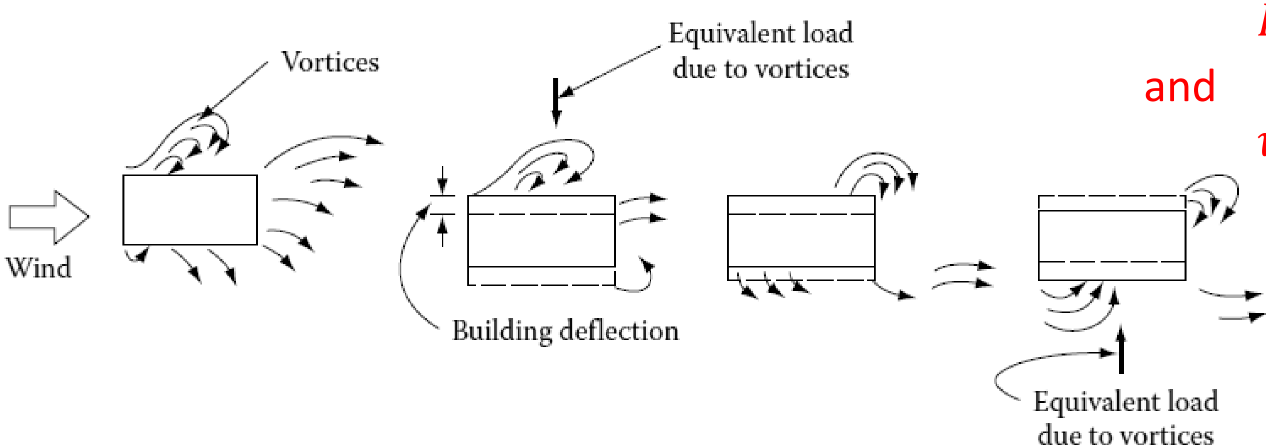
where v is the wind speed, taken as the critical wind speed v_{cr}
D is the depth of structure in metre

Important especially when

$$R_e > 3.5 \times 10^6$$

and

$$v_H > v_{cr}$$



Overall procedures

Types of load

- Permanent load
- Variable load
- Accident load
- *Seismic load*

Representative value

- Characteristic value
- Combination value
- Frequent value
- Quasi-permanent load

Load combination

- ULS
  - Fundamental
  - Accidental
- SLS
  - Characteristic
  - Frequent
  - Quasi-permanent