(2) Characteristic Values of Loads

The loads applying during construction stage and design service life are considered under the combination of loads. Loads can be divided into three categories:

- (a) **Permanent load:** the load whose variation is very small, such as dead load, static earth pressure, prestressing force, load actions caused by drying shrinkage and creep of concrete.
- (b) Variable load: the load whose variation occurs frequently or continuously, such as live load, effect of temperature, wind load, snow load, etc.
- (c) Accidental load: the load whose frequency of occurrence in design service life is very small, however, once it occurs, it will cause very serious damage, such as strong earthquake, collision loads, etc.
- The characteristic values of loads are determined respectively for the limit states concerned:
- (a) For the examination of the ultimate limit state: the expected values for the maximum or minimum loads occurring during construction stage and design service life of the structure are used.
- (b) For the examination of the serviceability limit state: the loads whose magnitude appears relatively frequently during the design service life of the structure are used.
- (c) For the examination of the fatigue limit state: the variable loads occurring during the design service life of the structure are used.

1.3.3 Partial Safety Factors

Five partial safety factors are used in the limit state design method stipulated in JSCE specification.

(1) Material Factor, γ_m

This safety factor reflects the difference of material properties between test specimens and actual structures, the time-dependent deterioration of the material strength, and the possibility of weaker material strength than the characteristic value, etc. In reinforced concrete, there are mainly two factors related to concrete and reinforcing bars, respectively. The material factor is used to determine the design value of material strength as follows:

$$f_d = f_k / \gamma_m \tag{1.5}$$

where, f_d : the design value of material strength f_k : the characteristic value of material strength

(2) Load Factor, γ_f

This factor is concerned with the uncertainties in the evaluation of external loads. It also considers the unfavorable deviation from the characteristic value, etc. The load factor is used to determine the design value of load as follows:

$$\boldsymbol{F}_d = \gamma_f \boldsymbol{F}_k \tag{1.6}$$

where, F_d : the design value of loads

 F_k : the characteristic value of loads

(3) Structural Analysis Factor, γ_a

This factor is related to the uncertainties in the structural analysis for computation of member forces.

(4) Member Factor, γ_h

This factor is concerned with the uncertainties in computation of capacities of members, the importance or the influence of members on the entire structure, etc.

(5) Structure Factor, γ_i

This factor is related to the importance of the structure, and the influence on the society when the structure reaches the limit state.

Table 1.3 Standard values for partial safety factors

Safety factor Limit state	Material factor, γ_m		Mombor	Structural	Load	Structure
	concrete, γ_c	steel, γ_s	factor, γ_b	analysis factor, γ_a	factor, γ_f	factor, _{Yi}
Ultimate limit state	1.3	1.0	1.15-1.30*	1.0-1.2	1.0-1.2	1.0-1.2
Serviceability limit state	1.0	1.0	1.0	1.0	1.0	1.0
Fatigue limit state	1.3	1.0	1.0-1.1	1.0	1.0	1.0-1.1

*: The value is recommended to increase for the shear capacity in the seismic design.

1.3.4 Examination Method of Limit States

According to a reliability design concept, there are three levels of checking safety of a structure; such as the designs using (1) the probability, (2) the safety index, and (3) the characteristic value and safety factors. The third one (simplest one) is called as level I method. In the level I limit state design method, the characteristic values and safety factors are used to check the safety of a structure at each limit state.

The format for checking is,

$$\frac{\gamma_i \gamma_a S(\gamma_f F_k)}{R(f_k / \gamma_m) / \gamma_b} \le 1.0$$
(1.7)

It is noted that in case the functions of $S(\gamma_f F_k)$ and $R(f_k/\gamma_m)$ are linear, i.e., if $S(\gamma_f F_k) = \gamma_f S(F_k)$ and $R(f_k/\gamma_m) = R(f_k)/\gamma_m$, Eq.(1.7) can be written as,

$$S(F_k) \leq \frac{R(f_k)}{\gamma_i \, \gamma_a \, \gamma_b \, \gamma_f \, \gamma_m}$$
(1.8)

When Eq.(1.1) and Eq.(1.8) are compared each other, it is found that in principle the procedures to check the safety in the allowable stress design and the limit state design are the same.

Even in the limit state design of reinforced concrete structures, the member force *S* is obtained by linear structural analysis. However, the load carrying capacity *R* is obtained by considering nonlinear behavior of reinforced concrete material, i.e., $R(f_k/\gamma_m)$ is a nonlinear function. Hence, the results of allowable stress design and limit state design methods are completely different depending on the degree of nonlinearity of RC materials.

- **1.4 Structural Analysis**
- In general there are two types of nonlinearities involving RC structural behaviors:
- (1) Material nonlinearity: inelastic effect, interaction between concrete and reinforcing steel.
- (2) Geometrical nonlinearity: finite deformation effect (ex. buckling)

In the design, the ideal concept to check the safety of structures is to perform a nonlinear analysis of structures considering both material and geometrical nonlinearities and to check whether the structure reaches the ultimate state or not (Fig. 1.6).



Fig. 1.7 Current concept for safety assessment