CHAPTER 1 GENERAL CONCEPTS

1.1 Scope of Applications

These recommendations incorporate the present state of the art for estimating appropriate loads for the structural design of buildings. Most recent findings have been reflected as far as possible. After the previous revision, the Hanshin-Awaji disaster occurred and a great attention on structural safety has been drawn. In AIJ, various design methods besides the allowable stress design have been developed and compiled into design guidelines. Reflecting this situation, this revision provides common way of determination of design loads with disregard to design methods. However, those considered as incomplete or insufficient for design purposes are introduced in either commentaries or recommendations apply to ordinary buildings and shall not be directly applied to buildings using a new construction system or new materials, to those of extremely large size with long spans or heights, or to those for a special use. In these cases, further investigations have to be done into fundamental requirements, as explained in 1.2. Nevertheless, it is strongly recommended that each article be applied based on the principles of these recommendations.

Where the recommendations incorporate results of surveys and research, logical estimation procedures are included. However, where new surveys or research suggest modifications or improvements, the relevant parts can be replaced. In particular, although basic load values are estimated from appropriate latest available information analyses and extensive investigations of the more recent data should be utilized to obtain more reliable estimations whenever possible.

These recommendations are based on the stochastic model of load intensity. In other words, to fulfill the safety and serviceability requirements of structures. Required degrees of safety and serviceability for ordinary structures have to be satisfied at the maximum load level estimated from statistical load data. The 50- to 100-year return-period loads for snow, wind or earthquake, or the maximum of 100 live load samples, may well be evaluated with reasonable reliability. However, the estimation reliability of other rare events is limited. It may not be appropriate to estimate a meteorological event that occurs once in several thousands years or a rare event among tens of thousands of samples by a simple extrapolation of available statistical data. However, such extrapolations based on the stochastic model certainly provide some information on rare events and are also regarded as a meaningful tool in assigning a degree of reliability for safety and serviceability. It is also important to investigate the upper limit load level by a deterministic approach. For the stochastic method used in these recommendations may be necessary, e.g., possible maximum load recent scientific findings, or the worst live load conditions may be considered by simulating a scenario of future variation of usage. A high degree of engineering judgment is required in such cases. Some deterministic estimation may help to improve the stochastic models and to contribute to the formation of a social consensus for structural safety.

In general, the loads can be estimated in the design procedure. These recommendations are applicable not only to allowable stress design but also to ultimate strength design and limit state design. A uniform "basic load" is defined to provide a reference load for all design procedures. In allowable stress design, the design load is determined by considering the occurrence frequency of the maximum load in terms of return period conversion factor. In ultimate strength design and limit state design the design load is obtained as the basic load multiplied by an appropriate load factor. The specific values for the appropriate frequency of occurrence or load factor estimation are left open to individual design frame-works and only a few examples are shown in the commentaries.

Load evaluation for design calculation based on allowable stress includes design checking of bearing capacity design in a seismic design. Provisions in law do not always reflect the state-of-the-art findings. In the recommendations, determination of design loads is dependent upon designers' judgment that is related to required degree of safety and serviceability. In this respect, laws can be regarded as good reference. Note that appropriate design loads determined according to the recommendations may not be legal.

1.2 Fundamental Concept

1.2.1 Structural performance

(1) Safety In a structural design of a building, a designer should make use of his/her knowledge and technology to meet the requirements that are imposed on structural performance of a building. These requirements are not only from the building owner, but also from the public and from the regulators.

There are several requirements for a building. "Safety" and "serviceability" are closely related to structural design. The goal of structural design is to determine an appropriate structural shape in such a way that the building possesses safety and serviceability performance requirements against anticipated loads and disturbance during its service life.

Buildings of all kinds and sizes, for both private and public use, must be structurally safe not only against natural hazards but also against dead and live loads. This is required by the building standard law, and this requirement is regarded as the minimum level to ensure public safety and protection of property. To confirm that the minimum level of structural safety is achieved, regulations require structural calculations for buildings of prescribed sizes and constructions.

Engineers must comply with these minimum requirements, but at the same time make judgments on the target structural performance by considering economic rationale. When a building owner requires a higher safety level than that required by the regulations, the engineer should take these higher requirements into account. In such cases, he/she has to consider the social influence of the building based on the owner's demands. The engineer should seek desirable building construction methods, taking into account the efficient use of the limited resources of the earth.

Society cannot expect that buildings will be safe whatever the extreme load is. Since building construction is an economic activity, safety requirements must take account of economic rationale. An appropriate balance between safety and economics is an essential requirement. However, if the economic aspect is emphasized in the design, construction and usage of buildings, the safety requirement may be underestimated. A low safety standard could lead to a considerable loss of economic activity in the event of an earthquake, typhoon or heavy snowfall.

When a building belongs to a private owner, the minimum safety requirement depends not only on the owner but also on the regulations. However, such regulatory requirements do not exist as an absolute standard but vary according to the technical standards, economic situations, societal demands, accumulations of disaster experience and so on. Therefore, design regulations should keep pact with these environmental changes. The design load for safety criteria shall be determined by considering various demands in the planning stage.

(2) Serviceability During the structural design procedure, in addition to the safety requirements, the serviceability of the building has to be examined under sustained loads or relatively frequent loads. In the limit state design, the serviceability limit state is generally defined for the serviceability criteria. Examples of serviceability are as follows:

- deflection which influences the use and exterior view of structural components or non-structural components.
- excessive vibration which causes discomfort to the occupants or influences non-structural components or equipment (in particular the case of resonance).
- minor damage which influences the durability of the structural components, the efficiency of non-structural components or the exterior view (including cracks).

In the allowable stress design, investigations for sustained loads often correspond to serviceability checking, but they are not carried out separately from safety checking. There may be additional design requirements for serviceability.

(3) Reparability In a structural design, safety limit, serviceability limit and reparable limit may be of concern. For example, it was a serious problem during the 1995 Kobe earthquake that there were many buildings which had not structural safety-related problems but were not functioning at all and needed proper repair for their expected use. The reparable limit is not so clear as safety and serviceability limits since it is related not only to social and economical issues but also how the owner and designers treat it.

However, a section of "reparability" has been added because of current consciousness of environmental impact. As reparability is not a design target yet in a current practical design, it is not included in the section "2.3.3 load combination for limit state design."

1.2.2 Structural analysis

There are two types of methods; static and dynamic analyses. In these recommendations, a dynamic analysis is used only for special types of structures, a static analysis is for ordinary structures. However, a dynamic analysis may be carried out based on the load characteristics stated in the recommendations.

The designers should keep in mind that there still exists some discrepancy between the results form the analysis and actual phenomena.

1.2.3 Proper design and construction

To maintain safety and serviceability, a great care has to be taken even in the construction as well as in-use situations. Errors in the process of design, construction and in-use may sacrifice safety. These errors cannot easily be incorporated in the determination of design loads. Therefore, these recommendations are made, provided that design, construction and use of buildings are adequate.

1.3 Definitions

Among terminology related to evaluation of loads, definition of terminology associated with the limit state design are given below.

load intensity: A physical quantity expressing the magnitude of load. It has the dimension of “force” or “force per unit area”. Dead and live loads: an average weight per unit area; snow load: a weight per unit area calculated from the ground snow depth; wind load: a wind pressure calculated from ten-minute mean wind speed; earthquake load: a story shear force calculated from PGA (peak ground acceleration) or PGV (peak ground velocity) on the engineering bedrock.

load factor: a partial safety factor in order to take account of uncertainty of load. The load uncertainty includes both variability of load itself and uncertainty associated with load evaluation methods.

resistance factor: a partial safety factor to take account of uncertainty of resistance.

reliability index: an index expressing a margin to the specified limit state, and one of quantitative expression of reliability. Letting G be a limit state function with a mean value μ_G and a standard deviation σ_G, the reliability index β is μ_G/σ_G.

probability of failure: the probability that undesirable state beyond the limit state associated with safety or serviceability occurs within the specified reference period P_f.

return period: the mean time interval r of the events that the load intensity exceeds a specified value. If the exceedance events are statistically independent, r can be obtained with p being the probability of exceedance event within a unit time period.

$$r = \sum_{i}^{\infty} ip(1-p)^{i-1} = \frac{1}{p} \tag{1.3.1}$$

reference period: an arbitrarily selected time period when evaluating the reliability index or probability of failure.

design lifetime: an assumed time period within which a building can be maintained as scheduled, is free from major repair and can fulfill the original usage.

References

1) Ang，A.H-S. and Tang，W.H.：Probability Concepts in Engineering Planning and Design - Decision，Risk，and Reliability，John Willey & Sons，Inc.，1984