# CHAPTER 1 GENERAL

## 1.1 Scope

**This Specification, 'Seismic Performance Verification', shall be used for the verification of seismic performance of general concrete structures.**

**[Commentary]** This specification 'Seismic Performance Verification' is used to verify seismic performance of concrete structures. This specification provides standard methods for seismic performance verification of concrete structures as well as structural details, which are the premise conditions for performance verification.

As for structural design, the previous versions of JSCE Standard Specification for concrete structures were named as 'Design (1996)' and 'Seismic Design (1996)'. The specification 'Design', in which limit state design method was adopted in 1986, had been used until this revision, and within that the methods for performance verification of concrete structures were mainly described. The specification 'Seismic Design', which was established in 1996, also described basically the methods for seismic performance verification of concrete structures. In order to indicate their contents clearly, the specification 'Seismic Design' is renamed as 'Seismic Performance Verification' in a manner similar to renaming of the specification 'Design' to 'Structural Performance Verification'.

There are several options in structural planning and design, which should satisfy the required performance. Originative structural planning and effective design basically come from the abundant ideas and experiences of design engineers, and are important in construction of structures. Therefore, standards for structural planning and design, which consider seismic performance, are described in '**1.3 Principles of seismic design**' and '**1.4 Aseismic structural planning**'.

General concrete structures to which this specification is applied indicate reinforced concrete, prestressed concrete and steel-concrete composite structures. Provisions of JSCE Standard Specifications for Concrete Structures such as 'Structural Performance Verification', 'Materials and Construction', etc. shall be considered applicable for provisions not described in this specification.

## 1.2 Definitions

**The following terms are defined for general use in this specification.**

**Beam element model: A model where a structure is represented as made up of a combination of one-dimensional beam elements.**

**Finite element model: A model where a structure is represented as made up of a combination of two or three-dimensional finite elements.**

**Nonlinear hysteretic model: A model that gives a nonlinear hysteresis in the stress – strain relationship of constitutive materials, or in the load – displacement relationship of a member or a structure under reversed cyclic loading.**

**Yield load of a member: Load at which a member reaches its yield point. In case of linear**

**members and planar members subjected to out-of-plane forces, this load is defined as the load at which the re-bars at the center of the resultant tensile force in the re-bars yield.**

**Yield displacement of a member: Displacement corresponding to the yield load of a member.**

**Ultimate displacement of a member: Displacement at which a member reaches its ultimate state. In case of linear members and planar members subjected to out-of-plane forces, this is defined as the maximum displacement where the load does not become lower than the yield load in the load – displacement envelope curve.**

**[Commentary]** Yield load of a member : The definition in this specification may be applied to any arbitrary cross sections such as circular and rectangular section with re-bars arranged in side, and is considered to be most appropriate for expressing the yielding of a member mechanically. Since the tensile force which occurs in re-bars is calculated so that the equilibrium condition may be satisfied in section analysis, the depth of the resultant force does not always coincide with the practical depth of the re-bars (see **Fig. C1.2.1**). Yield load based on this definition indicates 1-3% larger value compared with the case that re-bar at the angle of 45 degrees in the tensile side for circular section yields. In case of square cross section having equal amount of re-bars in each direction, this definition gives 5-6% larger yield load compared with the case that re-bar at the extreme tension fiber yields.

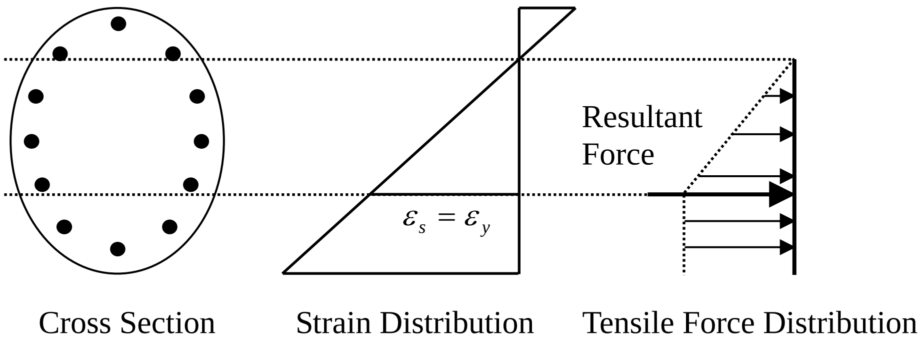


**Fig. C1.2.1 Yield criterion of a member**

## 1.3 Principles of seismic design

**(1) Seismic design shall be carried out with the object of not only ensuring safety of a structure during earthquakes but also preventing fatal damages affecting human life, as well as degradations in function of the structure affecting livelihood and production activities of inhabitants.**

**(2) Design earthquake ground motion shall be determined considering the magnitude of the earthquake, source characteristics, structure of local stratum between the epicenter and construction site, propagation characteristics and distance between the epicenter and the construction site, and topographical, geological and ground conditions of the construction site. In general, two kinds of design earthquake ground motions – Level 1 and Level 2 as given below, may be considered.**

- **(i) Level 1 Design Earthquake Ground Motion: earthquake ground motion that is likely to occur a few times within the lifetime of a structure.**
- **(ii) Level 2 Design Earthquake Ground Motion: very strong earthquake ground motion that has only a rare probability of occurrence within the lifetime of a structure.**

**(3) In principle, seismic performance level of a structure should be determined considering the design earthquake ground motion as well as effect of damage of the structure on human life, refuge, relief and rescue activities, prevention of secondary disaster, livelihood, economic activities, and difficulty and cost of restoration. In general, seismic performance level of a structure may be classified into the following three levels.**

- **(i) Seismic Performance 1 : Function of the structure during an earthquake is maintained, and the structure is functional and usable without any repair after the earthquake.**
- **(ii) Seismic Performance 2 : Function of the structure can be restored within a short period after an earthquake and no strengthening is required.**
- **(iii) Seismic Performance 3 : There is no overall collapse of the structural system due to an earthquake even though the structure does not remain functional at the end of the earthquake.**

**(4) Seismic design of a structure shall be carried out to ensure that the structure satisfies the required seismic performance level under the assumed design ground motion. In general, the following verification may be carried out.**

- **(i) The structure satisfies Seismic Performance 1 against Level 1 Earthquake Ground Motion.**

- **(ii) The structure satisfies Seismic Performance 2 or 3 against Level 2 Earthquake Ground Motion.**

**[Commentary]** (1) Civil engineering structures, in general, have high public sense and, smoothness in maintenance and insurance of their functions has a large influence on life of individuals, livelihood, social and productive activities. When setting seismic performance of a structure, it should be better to take its response characteristics into account according to the magnitude of an expected earthquake, as well as its behaviors during the earthquake and restoration ability after the earthquake. Needless to say that a destructive damage which leads to the loss of human life shall be prevented against a strong earthquake ground motion that has a rare probability of occurrence within the lifetime of a structure. In addition, from social and economic points of view, deterioration in functions of the structure should be avoided as much as possible, and livelihood and productive activities of inhabitants after the earthquake should be restored smoothly.

(2) Level 1 Earthquake Ground Motion corresponds to that which had been considered conventionally for most of civil engineering structures. Level 2 earthquake Ground Motion, on the other hand, takes into account inland type earthquakes in epicentral area in addition to large-scale plate boundary earthquakes which occur in the vicinity of land. Design earthquake ground motion can be set in various categories making the level of ground motion to correspond to its possibility of occurrence or expected damage in a concrete structure. In the present stage, however, the accuracy of the prediction of ground motion and evaluation of structural damage does not always give sufficient results. Therefore, two levels of ground motions indicated here may be set as design earthquake ground motions.

(3) Seismic Performance 1 means that the residual deformation of a structure after an earthquake remains sufficiently small. Unless the acting force reaches the yield load of a member, this seismic performance can be satisfied.

Seismic Performance 2 is that load carrying capacity does not deteriorate after an earthquake. In general, this performance may be thought to be satisfied in case that each constitutive member of a structure does not fail in shear during an earthquake and response deformation does not reach its ultimate one. In some special cases, residual deformation may be specified. In such a case, however, the residual deformation should be estimated by an appropriate method and assured that the estimated residual deformation remains within an allowable limit. Compared with the residual deformation of a structure, in general, that of a foundation including surrounding soil becomes larger and the appropriate evaluation methods becomes necessary. In case of structures such as wall type ones in which earthquake force acts mainly as in-plane force, large deformation capacity cannot be expected. In the design of such structures, it is necessary to provide sufficient shear capacity so that brittle failure may not occur.

Seismic Performance 3 requires that whole structural systems do not collapse due to self and imposed masses, earth pressure, hydraulic (liquid) pressure, and so on even if the structure becomes unrestorable after an earthquake. In case of concrete structures, generally Seismic Performance 3 can be satisfied if each constitutive member has enough safety against shear failure. In some structural systems , however, displacement of the whole structure becomes excessive, and additional bending moment as well as longitudinal displacement increase due to self weight. These may lead to self-overturning or collapse mechanism. As for these cases, it is necessary to confirm using appropriate method that the system does not reach such conditions.

The terms of “repair” and “strengthening” in the provisions represent the aim of restoring work from damaged condition. The term “repair” means the restoration work so that a damaged structure may be restored to its original condition, while the term “strengthening” means the one so that structural properties such as load carrying capacity and deformation ability may satisfy the required seismic performance.

(4) In the seismic design of a structure, it is necessary to set the seismic performance, which the structure should possess, according to the scale of considered seismic ground motion and its return period. In such cases, aim and function of the structure, degree of contribution and influence on the region and society, property worth, degree of influence on neighborhood when subjected to damage,

existence of alternative functional systems, difficulty of restoration work, and so on shall be considered.

As for the general civil engineering structures, consideration on the combination of the provisions indicated may be done. However, in case of special structures such as LNG underground vessels, examination should be done dividing Level 2 Earthquake Ground Motion into further two levels as the followings.

i) strong earthquake ground motion of which the probability of occurrence during the lifetime is relatively small

ii) very strong earthquake ground motion of which the probability of occurrence during the lifetime is very small