# Dynamic design criteria for tall buildings in Japan

# Dynamic Design Criteria for Tall Buildings in Japan

Critères dynamiques pour le calcul de bâtiments de grande hauteur au Japon

Dynamische Entwurfskriterien für Hochhäuser in Japan

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## 1. Introduction

The earthquake resistant design is most important in the structural safety in Japan. The design of low buildings under 45 meters are performed by the conventional static method based on "Seismic Co-efficient" method, that is, percent G method.

On the other hand, a unique "Dynamic Design Method" has been established for the high-rise buildings over the height of 45 meters. The procedure of this new method is shown in Fig.1. In this method, the dynamic response analyses are conducted with the aid of a computer using observed records of strong earthquakes as input waves. The strength and deformation of the structure are checked covering the elastic and elastic-plastic ranges, and if the results on stress and strain do not satisfy the design criteria established by the designers to control response stresses and/or deformations, the structural design must be revised and checked again. This procedure is the so-called "feed-back" system.

This paper presents the dynamic design criteria in this procedure and the earthquake response values of several examples.

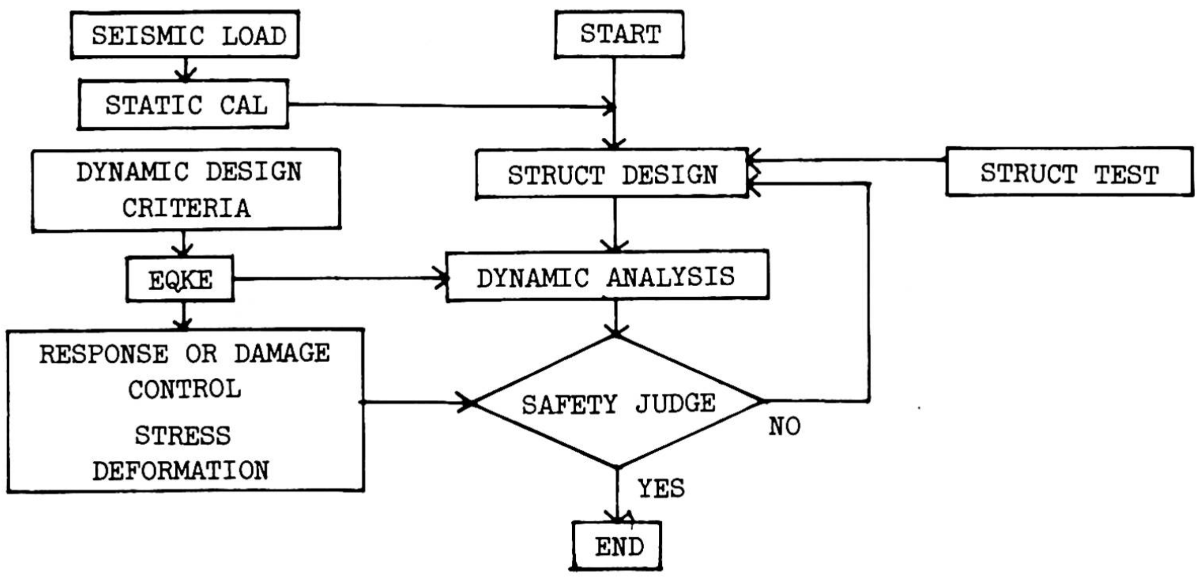



Fig.1 Dynamic Design Procedure of High-rise Building

## 2. Dynamic Design Criteria

Fig.2 shows the earthquake resistant design criteria set up by the authors' institute. Three degrees of earthquake intensity are assumed and against each degree, response limitations are respectively established.

For a minor or moderate earthquake, categorized as Class I, which occurs after and during which the behaviors of the structure can be confirmed by vibrations tests, the vibration must be controlled to be as small as possible to give no disturbance or discomfort to human. In other words, a high stiffness should be given to the structure in order to minimize the deformation. When an expected severe earthquakes hit, the stresses on all members of the structure must be less than the allowable values and also the secondary members should maintain safe condition. This category level, Class II, may be considered to correspond to the conventional code design level.

In the worst earthquake, hypothetically assumed as Class III, the structural and secondary members may exceed the elastic limit and suffer some damage but must not be severely damaged or collapse.

For the Tokyo region the authors usually assume the maximum acceleration of 0.2 - 0.3G as the Class II earthquake and 0.4 - 0.5G as the Class III earthquake.

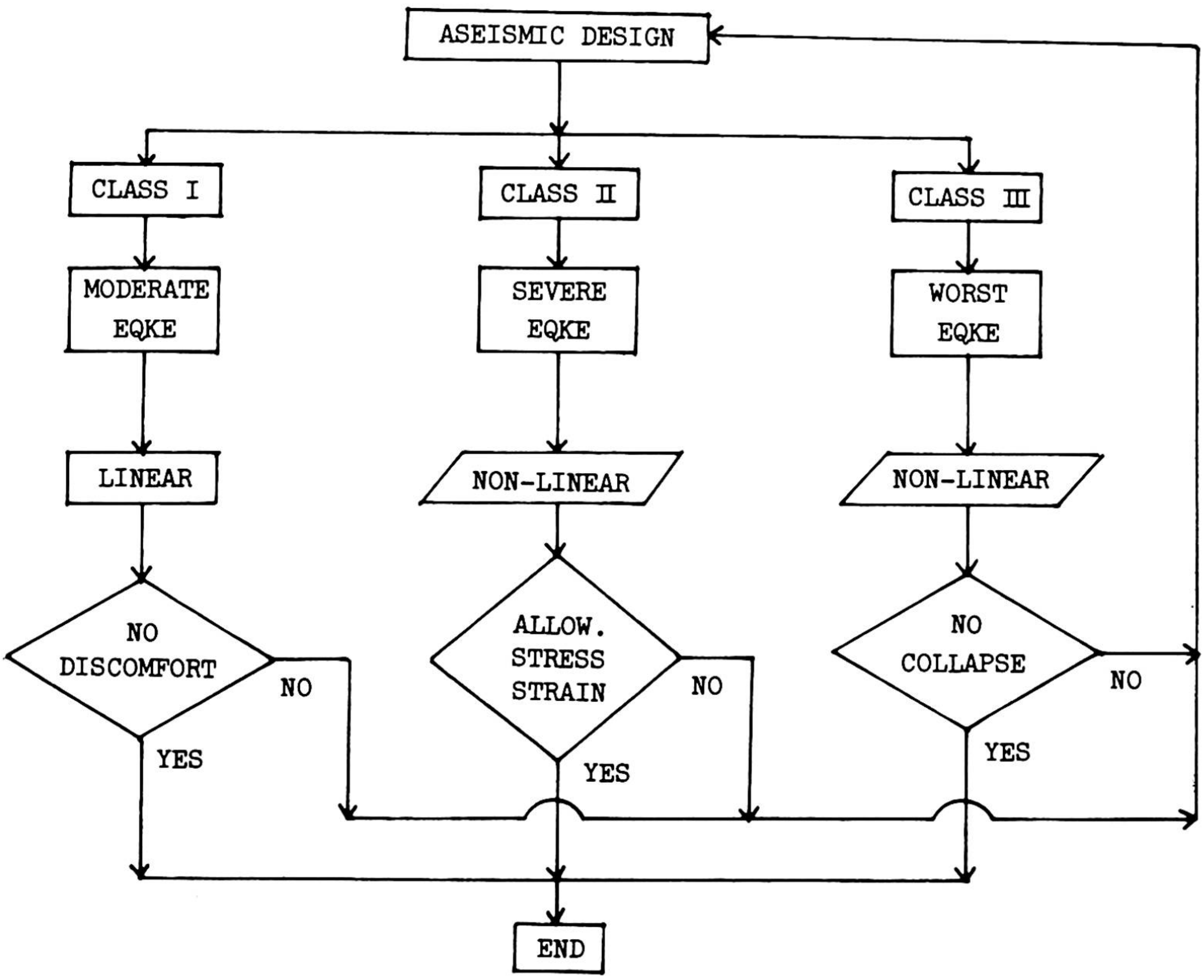



Fig.2 Dynamic Design Criteria Set Up by the Authors' Institute

## 3. Earthquake Response Values

The authors have undertaken to design and analyze many tall buildings in the way described above. In order to show the damage control, examples of maximum earthquake response values of three buildings are listed in Table 1.

The 60-story office building is under construction in Ikebukuro Subcenter of Tokyo and will be the tallest in Japan. (Photo 1) The earthquake resisting system of this building consists of rigidly connected steel framings with the special ductile reinforced concrete shear walls (slitted wall) as shown in Fig.3. Next 17-story office building consists of steel moment resisting framings only.

For these two high-rise buildings, the authors have assumed the maximum acceleration of 0.25G as the Class II earthquakes and 0.4G as the Class III ones in consideration of the important factor. All of these response values shown in Table 1 are appropriate for the design criteria.

Photo 2 shows the 4-story reinforced concrete garage building. Although the design of this building is in the category in which only the stress check is regulated by the conventional code, the dynamic analysis was performed especially in order to investigate the safety against earthquakes.

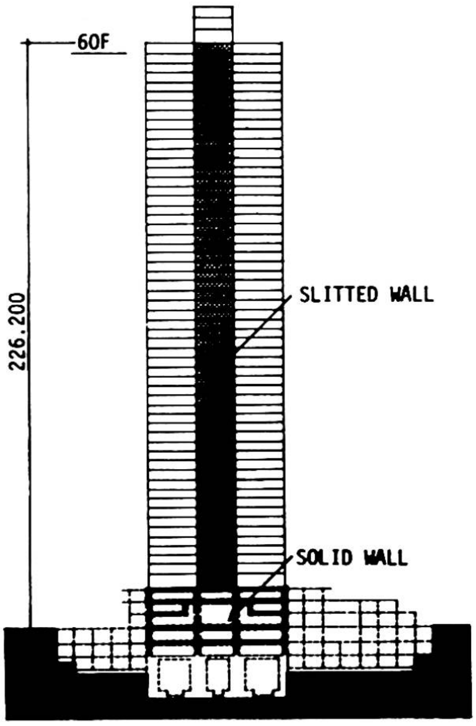
In this case the design criteria for tall building are not satisfied, but this building was designed to have sufficient ductility by placement of rebars in special arrangement shown in Fig.4.

Table 1 clarifies that for tall buildings the important problem in designing is the stiffness control, and consequently the tall buildings are given more than sufficient strength. On the other hand for low buildings it is important to control the deformability with satisfactory ductility as much as the strength.

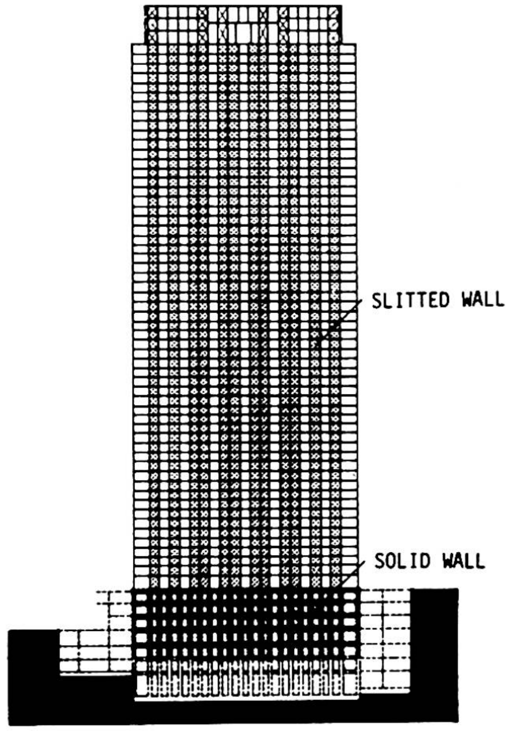
| Building (Structure) | Earthquake Intensity | Damage Control (Max. Value) | | |
|---|---|---|---|---|
| | | Strength | Story Defl. Angle | Ductility Factor |
| 60-story Office (Steel framing & R.C. Slitted Shear Wall) | 0.25G | Elastic | 1/400 | 0.7 |
| | 0.40G | Partially Yield | 1/260 | 1.3 |
| 17-story Office (Steel framing) | 0.25G | Elastic | 1/190 | 0.9 |
| | 0.40G | Partially Yield | 1/110 | 1.4 |
| 4-story Garage (Moment Resisting R.C. framing) | 0.20G | Yield | 1/130 | 1.3 |
| | 0.40G | Yield | 1/60 | 2.6 |

Table 1. Examples of Damage Control

Photo 1. Ikebukuro Subcenter Development (Right: 60-Story Office)




Transverse Direction




Longitudinal Direction

Fig.3 Framing Sections of 60-Story Office Building

Photo 2. 4-Story Reinforced Concrete Garage Building

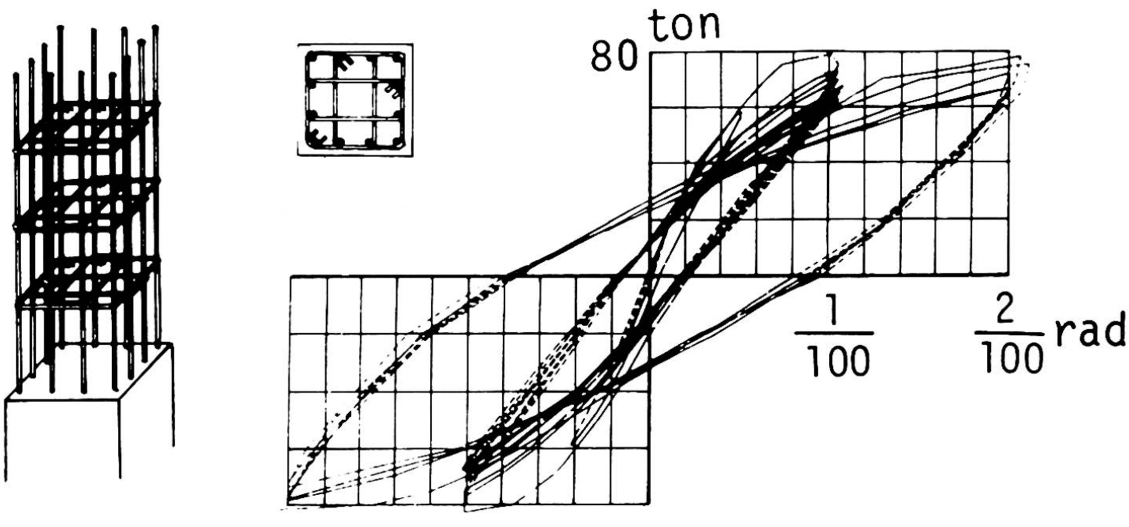



Fig.4 Shear-Deflection Hysteresis Loop of Tied Column Used in the 4-Story Garage Building

SUMMARY

The feed-back dynamic design system has been accepted in Japan as the most advanced of its kind for tall buildings over 45 meters. In this system dynamic design criteria are indispensable in order to evaluate the earthquake response values obtained from the dynamic analysis. Without those damage evaluations and controls, seismic design, in the true sense of the word, can never be established.

RESUME

La méthode dynamique par itérations successives est, au Japon, reconnue comme la plus avancée pour l'étude des bâtiments de plus de 45 mètres de hauteur. La connaissance des critères dynamiques pour le calcul est indispensable afin d'évaluer les réponses sismiques obtenues par l'analyse dynamique. Sans évaluation des dégâts et sans contrôle, une étude parasismique, aus sens propre du terme, ne pourra jamais être mise sur pied.

ZUSAMMENFASSUNG

Die iterative dynamische Berechnungsmethode wurde in Japan als die fortschrittlichste Methode bei Hochhäusern über 45 m angenommen. In dieser Methode ist die Kenntnis der dynamischen Kriterien für die Berechnung unerlässlich, um die Wirkung des Erdbebens nach der dynamischen Analyse abzuschätzen. Ohne diese Schadenermittlungen und Kontrollen ist eine seismische Berechnung und Bemessung undenkbar.

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