DEVELOPMENT OF SAFETY EVALUATION GUIDELINES FOR BASE-ISOLATED BUILDINGS IN JAPAN

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This paper describes the safety evaluation guidelines for ordinary base-isolated buildings, now under development in Japan.

Introduction

Design of all base-isolated buildings currently must go to the Ministry of Construction to obtain the Minister of Construction's Special Permit (as stipulated in the Building Standard Law Art. 38). This special permit is issued on condition that the particular design has passed the Building Center of Japan review.

The Building Center of Japan established two committees for this purpose. One is the Base Isolation Research Committee, chaired by Professor Masanori Izumi of the Tohoku University. This committee reviews the base-isolation system of each structural designer, design procedures, and design criteria in general. The other committee, the Base Isolation Safety Evaluation Committee, chaired by the writer, reviews the structural design of each base-isolated building. In other words, when a structural engineer wants to get approval on the design of a base-isolated building, he must first go to the Research Committee and have his base-isolation system and design method reviewed. He then goes to the Safety Evaluation Committee to have the individual building design reviewed, each time using his base-isolation system which has already been approved by the Research Committee.

The above-mentioned review system was deemed appropriate for the initial state of the development of base-isolated buildings. But as the number of such buildings and their designers increases, it was strongly felt that a simpler review system was needed. However, at the same time, it was also felt that a simpler review, which could be achieved according to stiff regulatory specifications, might interfere with free development of the state-of-the-art.

The Building Center of Japan established a third committee in 1986, an Ad Hoc Committee to study the vibration control technology in general, including the base isolation. This committee was chaired by the writer. The committee issued the State-of-the-Art Reports Vol. 1 in 1987 and Vol. 2 in 1988. In the third year, the committee was expanded to form three subcommittees. The first subcommittee was in charge of the gener review of the state-of-the-art on the vibration control capacity evaluation, and was chaired by Dr. T. Murota of the Building Research Institute. The second subcommittee was in charge of developing the base-isolation safety evaluation guideline, and was chaired by the writer. The third subcommittee was devoted to reviewing currently available isolating devices, and was chaired by Professor M. Izumi.

A brief description of the works by the above-mentioned second subcommittee, although the works are still far from complete, follows. It is expected that the base-isolation safety evaluation guideline will take its final form at the end of the fiscal 1989; i.e., March 1990. When the guideline is finally approved and effected by the Ministry of Construction, the following changes are expected to occur as to the review and approval procedure.

First, a relatively conventional and conservative base-isolation design can be reviewed directly by the building official of the local autonomy following each specified item in the guideline. This will greatly simplify the designer's role in obtaining official approval, as compared to the current review system. However, to not restrict any development toward the new technology which may not be covered by the guideline, a second possibility exists; i.e., the current procedure to go through the Research and Safety Evaluation Committees of the Building Center of Japan will remain available.

Scope of the Safety Evaluation Guideline

The guideline recognizes two types of soil of three types as specified in the Building Standard Law and its Enforcement Order: Type I: hard soil; and Type II: intermediate soil. The use of a base-isolation concept for a structure on soft soil would have to be investigated from advanced scientific and engineering viewpoints. Hence, it was excluded from the guideline and was left to the current review procedure.

To have variety in application of the guideline, it specifies classifications in the design of superstructures and the isolators. Under the action of Level 2 earthquake motion,[a] the superstructure must satisfy one of the following three conditions:

S-1: no yielding of members is permitted

S-2: yielding, but no story mechanism, is permitted

S-3: mechanism, but no excessive drift, is permitted.

Also under the action of Level 2 earthquake motion, the maximum displacement of isolations must remain:

B-1: within stable (allowable) limits

B-2: within insured capacity limits.

Combination of the above classification produces a matrix as illustrated in Table I. Notations A^+, A^-, B^+, B^-, and C correspond to the safety evaluation levels, where level A^+ design is supposed to be the most conservative, hence inherently safe, and level C design takes the opposite side. Differences in the safety evaluation levels will result in a different number of required safety evaluation items. Level A^+ design will require the least number of items, with level C design requiring the most.

Safety Evaluation Items

Following are the inclusive items for level C design. As the level goes up toward level A^+, fewer items will apply, as mentioned above.

1. Architectural Design
2. Soil Condition

    Type of soil

    Boring

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[a]Level 1 and Level 2 earthquakes refer to the levels as currently used in the dynamic design of high-rise buildings. Level 1 earthquake corresponds to "once-in-a-lifetime" event, and a Level 2 earthquake is regarded as much higher than that, corresponding to "probable maximum" event. They are currently taken, for buildings in the Tokyo area, for example, to be 25 and 50 cm/s, respectively, in terms of maximum ground velocity of the earthquake motion.

3. Structural Design
   - Design principles
   - Material and strength
   - Design load
   - Behavior under design load
   - Ultimate behavior
4. Isolator Design
   - Specification for bearings
   - Specification for dampers
   - Arrangement and allowable values
5. Earthquake Response Analysis
   - Analysis principles
   - Method of analysis
   - Analytical models
   - Natural period
   - Earthquake motion
   - Evaluation for Level 1 earthquake
   - Evaluation for Level 2 earthquake
   - Evaluation for safety margin
6. Other Evaluations
   - Wind
   - Architectural details
   - Equipment design
   - Durability
   - Fire protection
   - Construction
   - Maintenance

Safety Margin of Base Isolation

There is "evaluation for safety margin" in the itemized list of Table I. This item means a safety check for earthquake motion in excess of Level 2. It is generally agreed that a base-isolated building should have similar seismic safety as an ordinary high-rise building, in view of the similar fundamental period of vibration. Nevertheless, no safety margin check is required for ordinary high-rise buildings for any earthquake motion in excess of Level 2. Figure 1 attempts to explain the difference between ordinary high-rise and base-isolated buildings, from a rather personal point of view.

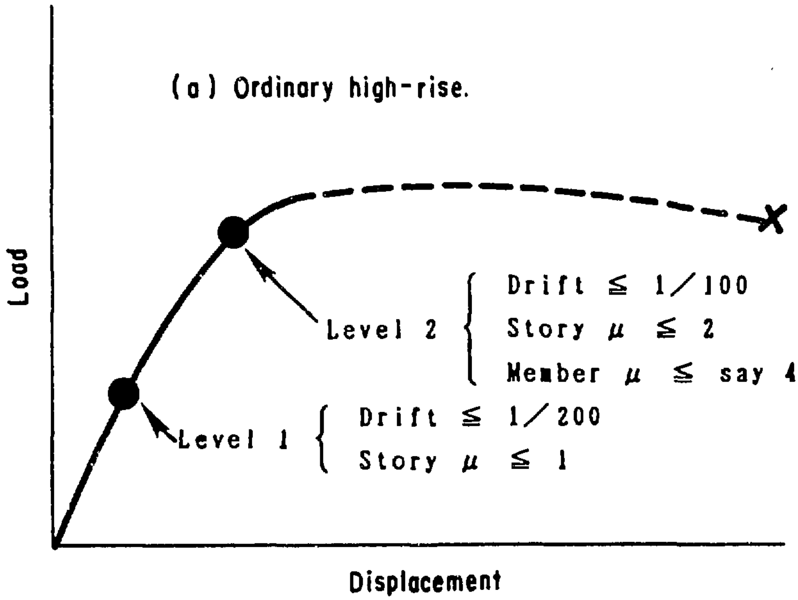
Figures 1(a) and (b) illustrate schematic lateral load-deflection curves for ordinary high-rise and base-isolated buildings, respectively. In the case of base-isolated buildings, it is meant to be the load-deflection relationship for the isolating devices; i.e., the most critical layer of the structure. Design points corresponding to design earthquakes of Levels 1 and 2 are shown on the curves.

For ordinary high-rise buildings, current structural designs almost always remain in the range as shown in Fig. 1(a). In the course of structural design, engineers do not opt to explore the available deformation capacity beyond Level 2, knowing there is ample reserve deformation capacity. This is illustrated by the broken line in the figure.

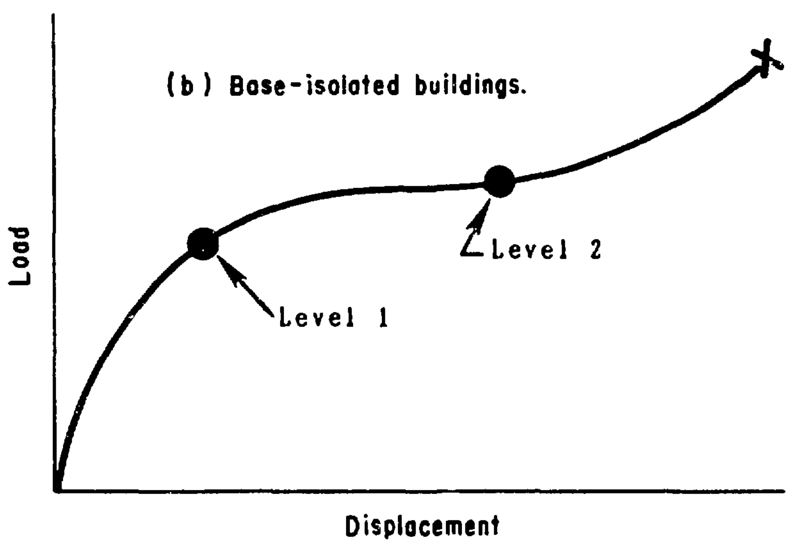
For base-isolated buildings, on the other hand, the end of our world is very clearly known, in terms of deformation capacity of base-isolation devices. Hence, it is necessary that a safety margin should be quantitatively explored beyond the Level 2 point. What kind of safety margin check should be employed is left to the judgment of the designer. There is no explicit requirement for the amount of factor of safety that should be provided. The state-of-the-art for base isolation is still in its developing stage, and a general social consensus for the seismic safety of this new kind of structure is yet to be developed.

Table I
Safety Evaluation Levels

	B-1 within stable lim.	B-2 within insured cap.
S-1 no yield	A^+	B^+
S-2 no mech.	A^-	B^-
S-3 mech.	C	C



(a) Ordinary High Rise



(b) Base-Isolated Buildings

Fig. 1. Safety Margin