STRUCTURAL CONTROL IMPLEMENTATIONS IN JAPAN

Akira NISHITANI[1]

SUMMARY

The recent state of structural control in building applications is presented in particular focusing on base isolation and active structural control. To date more than 650 buildings have been already approved to be base-isolated and more than 30 buildings have employed active control systems in Japan.

INTRODUCTION

For the last decade or so structural engineers have eyewitnessed the beginning of an innovative breakthrough in the design of civil engineering structures. It is the beginning of structural control. However, the philosophy of structural control itself is not very new. As mentioned quite often, the basic philosophy of structural response control was proposed and discussed by Kobori and Minai in their two consecutive papers (1960a and 1960b). In these papers, several fundamental ideas for structural-response-controlled buildings were comprehensively presented. In his other papers (1956, 1958) following their proposal, Kobori kept mentioning one of the principal ideas of structural control that the introducing of artificial nonlinearization into a building would provide the building with the same effect as automatic response control. In the United States, on the other hand, Yao presented his idea of active control of structures in 1972 by introducing the terminology of “structural control” into civil engineering field.

Along with the rapid development of computer-related technologies, the idea of structural control has fascinated the interests and concerns of structural engineers and has brought about many actual examples of passive- and active-controlled structures. In terms of the implementations of structural control systems to actual buildings, Japan has a variety of examples. This paper discusses what is going on with regard to structural control in the current state in Japan.

2. BASE ISOLATION

Following the Japanese Building Standard Law, certain particular kinds of buildings to be constructed in Japan, such as base-isolated buildings and high-rise buildings with the height of over 60 meters, etc., are required to get the permission of the Minister of Construction. In regard to base isolated buildings, they must be approved by the Base Isolation Building Appraisal Committee at the Building Center of Japan (BCJ) in order to get the Minister’s permission. As may be mentioned from time to time, the buildings with base isolation systems have demonstrated an active increase in their numbers since the 1995 Hyogoken-Nanbu earthquake. As of August 1999 the total number of appraised cases for base isolation buildings are over 650. At the end of March 1995 (just after the Hyogoken-Nanbu earthquake in January 1995 and also ten years after the establishment of the Base Isolation Building Committee of BCJ), however, only 82 cases had been appraised by the Committee during the first ten years from April 1985 to March 1995. The number of buildings with base isolation systems has rapidly increased by a factor of about eight for these four and half years after the Hyogoken-Nanbu

[1] *Department of Architecture, Waseda University, Tokyo, Japan. Email:akira@nstn.arch.waseda.ac.jp*

earthquake. These figures demonstrate how popularly the base isolation technology has kept being utilized since that destructive earthquake in the Kobe area.

There are two topics that should be mentioned with respect to the recent state of base isolation implementations.

The first thing is with regard to the types of rubber bearings utilized. In the ordinal design of base isolation buildings, three kinds of multilayered laminated rubber bearings are mostly used. They are: (1) natural rubber bearing; (2) high damping rubber bearing; and (3) lead plug rubber bearing. The first type of isolators have to be used together with steel bar dampers, steel coil dampers, lead dampers or hydraulic dampers or a combination of these dampers, while the second and third types can be implemented independently without any dampers used. Most of the base isolation buildings used to employ natural rubber bearing isolators in conjunction with dampers. The observation of the lately appraised building cases, however, seems to demonstrate the gradual increase of high damping rubber isolator systems and lead plug rubber bearing systems. In August 1999, for instance, 13 new base isolation building projects were submitted to the Base Isolation Committee for the Appraisal. Among them, five, three, and three cases use, respectively, certain combinations of natural rubber bearings and dampers, high damping rubber bearings, and lead plug rubber bearings. And the other two cases employ sliding bearing isolator systems, which are different from the rubber bearing isolators already mentioned.

The second is the development of relatively new type of base isolation systems. These new systems have been mainly developed for wooden, reinforced or steel residential houses with two or three stories . They are other isolation systems than rubber-type bearing isolators and are categorized as sliding bearing and ball bearing isolators. Compared to the frequently used rubber bearings, they should be relatively low priced. Since houses do not have heavy-weight and thus the vertical load to be carried by each isolator is quite small, the ordinal rubber bearing isolators are not necessarily appropriate. In making any small ordinal house base-isolated, it is needed to pay attention to its response to wind load because of its weight. In addition, it has been determined in Japan that the new Building Standard Law is going to be effective in the year of 2000. In accordance with the new Building Standard Law, some of the approval procedures for base isolation buildings are going to be revised. Some kinds of wooden houses with base isolation systems will be approved with simpler procedure than now. With relation to this movement, it is expected that more and more base-isolated houses will be constructed. Consequently, much more varieties of isolators will expectedly be developed and utilized in small residential houses.

3. ACTIVE CONTROL OF STRUCTURES

It has passed about ten years since the first building in the world to apply active structural control system, Tokyo Seiwa Building, was completed in 1989. According to the latest information about active-controlled buildings as of June 1999, more than 30 buildings have employed either active, hybrid, or semi-active control systems in Japan. Their names and information are shown in Appendix. It is found that during the recent two years from 1997 to 1998 nine buildings with certain active control systems were born. Compared to base isolation technology, however, active structural control is still under development, being at the level of providing living or working comfort to the building occupants but not at the level of ensuring the safety of a building against severe seismic excitation.

Among a variety of active control technologies, semi-active control seems promising and practical as a means of achieving the ultimate purpose of providing seismic protection to structures in case of any severe seismic event. Semi-active control is philosophically to control the structural response reduction more efficiently with less energy. In semi-active control, control operation is conducted only at the moment certain change or adjustment is needed in the control system. It seems to play the leading role in the future stage of active structural control. More and more papers discussing the applications of semi-active control to buildings have been lately published by research and practicing engineers.

4. CONCLUSION

The recent state of structural control in Japan has been discussed particularly with the focus on base isolation and active control.

REFERENCE

Housner, GW., et al (1997), "Structural Control: Past, Present and Future", *Journal of Structural Engineering*, ASCE, 123(9), pp897-971

Kobori, T. (1956), "Quake Resistant and Nonlinear Problems of the Structural Vibrations to Violent Earthquake", *Journal of Kyoto University Disaster Prevention Laboratory, Fifth Anniversary Edition*, pp116-124 (in Japanese)

Kobori, T. (1958), "The Direction of Earthquake Resistant Engineering", *Journal of Architecture and Building Science,* 1958.12, 73(857), pp5-9 (in Japanese)

Kobori,T and Minai,R.(1960a), "Analytical Study on Active Seismic Response Control: Seismic-response-controlled Structure 1", *Transaction of Architectural Institute of Japan*, 66, pp257-260 (Japanese)

Kobori,T and Minai,R.(1960b), "Condition for Active Seismic Response Control: Seismic-response-controlled Structure 2", *Transaction of Architectural Institute of Japan*, 66, pp253-256 (Japanese)

Nishitani, A. (1998), "Application of Active Structural Control in Japan", *Progress in Structural Engineering and Materials*, 1(3), pp301-307

Yao, JTP. (1972), "Concept of Structural Control", *Journal of the Structural Division*, ASCE, 98(ST7), pp1567-1574

APPENDIX: ACTIVE-CONTROLLED BUILDINGS IN JAPAN

The presented list is in the following order: Name (Location, Year of construction), Main structure, No. of stories above ground, Height, Control type. Some of further detailed information was given by Housner et al (1997) and Nishitani (1998).

Kyobashi Seiwa Bdg.(Tokyo, 1989), Steel, 11 stories, 33 m, AMD

Kajima Research Institute Bdg. No.21 (Tokyo, 1990), Steel, 3 stories, 12 m, AVS

Sendagaya INTES (Tokyo, 1992), SRC column and Steel beam, 11 stories, 44 m, AMD

Applause Tower (Osaka, 1992), Steel, 34 stories, 161 m, AMD

Kansai Airport Control Tower (Osaka, 1992), Steel, 7 stories, 86 m, HMD

Osaka ORC200 (Osaka, 1992), Steel, 50 stories, 200 m, HMD

Ando Nishikicho Bdg. (Tokyo, 1993), Steel, 14 stories, 54 m, HMD

Yokohama Landmark Tower (Yokohama, 1993), Steel, 70 stories, 296 m, HMD

Long Term Credit Bank (Tokyo, 1993), Steel, 21 stories, 129 m, HMD

Porte Kanazawa (Kanazawa, 1994), Steel, 29 stories, 121 m, HMD

Shinjuku Park Tower (Tokyo, 1994), Steel, 52 stories, 232 m, HMD

RIHGA Royal Hotel Hiroshima (Hiroshima, 1994), Steel, 35 stories, 150 m, HMD

MHI Yokohama Bdg. (Yokohama, 1994), Steel, 34 stories, 152 m, HMD

Hikarigaoka J City Bdg. (Tokyo, 1994), Steel, 24 stories, 100 m, HMD

Hamamatu ACT City (Hamamatsu, 1994), Steel, 46 stories, 212 m, HMD

Riverside Sumida (Tokyo, 1994), Steel, 33 stories, 134 m, HMD

Hotel Ocean 45 (Miyazaki,1994), Steel, 43 stories, 154 m, HMD and TMD

Osaka World Trade Center Bdg. (Osaka, 1995), Steel, 52 stories, 252 m, HMD

Dowa Kasai Phoenix Tower (Osaka, 1995), Steel, 28 stories, 144 m, HMD

Rinku Gate Tower Bdg. (Osaka, 1995), Steel and SRC, 56 stories, 255 m, HMD

Hirobe Miyake Bdg. (Tokyo, 1995), Steel, 9 stories, 30 m, HMD

Plaza Ichihara (Chiba, 1995), 12 stories, 61 m, HMD

HERBIS Osaka (Osaka, 1997), Steel, 40 stories, 189 m, AMD

Nisseki Yokohama Bdg. (Yokohama, 1997), Steel, 30 stories, 132 m, HMD

Itoyama Tower (Tokyo, 1997), HMD

OTS Elevator Test Tower (,1998), Steel, 39 stories, 154 m, HMD

Odakyu Southern Tower (Tokyo, 1998), Steel and SRC, 28 stories, 150 m, AMD

Bunka Fukushoku Gakuin (Tokyo, 1998), Steel, 20 stories, 90 m, HMD

Ooita Oasis Plaza 21 (Ooita, 1998), Steel, 20 stories, 92 m, HMD

Kajima Shizuoka Bdg. (Shizuoka, 1998), Steel, 5 stories, 20 m, AVD

Shinagawa Inter City Bdg. (Tokyo, 1998), Steel, 32 stories, 145 m, HMD