FUTURE PERSPECTIVE OF STRUCTURAL CONTROL IN EARTHQUAKE ENGINEERING

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SUMMARY

This paper briefly presents a current of research on semiactive control which is actually effective for reducing structural responses due to large earthquakes. To mitigate earthquake hazards, it is necessary to integrate different technologies in three stages: before, during and after the earthquake. This is established by an Integrated Hazard Mitigation System. Urban society should become integrated in the near future. Therefore, the author further stresses the necessity of Urban Control.

STRUCTURAL CONTROL FOR LARGE EARTHQUAKES

One of the important missions of structural control is to ensure the safety of structures and cities in large earthquakes. An earthquake motion would be unpredicted, uncertain and obscure even in the future, so that a structure should control its own responses by structural control. The continuous and vigorous research on structural control has born fruit, some of which has already been adopted in actual building structures [Kobori, 1998]. This research has also stimulated global and interdisciplinary activities giving rise to a wide variety of interesting work in many fields.

Various structural control systems have already been proposed. The author has stressed that, for effective control during large earthquakes, it is necessary to employ the variable structural characteristic control the author has already proposed [Kobori, 1992]. This may be realized by semiactive control systems. The authors are the first in the world to develop a semiactive control system, the Active Variable Stiffness (AVS) system, and they installed it in an actual three-story building in 1990 (Fig. 1) [Kobori, 1993]. The Semiactive Damper system (Fig 2) [Niwa, 1998] which has been installed in the Kajima Shizuoka Building completed in 1998 is also a semiactive control system. Subsequent observation records and simulation analyses have demonstrated its effectiveness. The semiactive control system has the following advantages, especially in large earthquakes: (1) it requires only a little external power, (2) the system device is simple and easily maintained, (3) it is compact and inexpensive. Thus, it is practical for reducing structural responses to large earthquakes. This has inspired intensive research and development on these systems [Kobori, 1998].

Semiactive control systems have been studied in various ways. The mechanism and systems should be becoming increasingly reliable, robust and practically simple. Furthermore, the design methodology of structural control should be established on the basis of performance criteria for evaluating building safety and function. However, the most important requirement is to develop control strategies for large earthquakes which have quite variable characteristics. By resolving these kinds of problems, structural control can systemize the technology for performance design and ensure security against earthquake disasters.

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2. INTEGRATED HAZARD MITIGATION SYSTEM

In urban areas, people's daily lives depend on complicated sociological bases. We depend on a rapidly developing infrastructure such as essential services and computer systems. If a large earthquake suspends this infrastructure, people's and companies' activities may be interrupted for a long time. The interruption could influence the economies not only of the immediately affected area, but also globally. To mitigate such earthquake hazards, it is necessary to integrate different technologies in three stages: before, during and after an earthquake. This is called an Integrated Hazard Mitigation System (Fig. 3).

Before an earthquake, it is necessary to carry out a seismic assessment of old structures and to monitor the health of important structures such as highway bridges. Furthermore, it is necessary to predict social damage based on scenario earthquakes. These pre-earthquake activities link the idea for recovery and reconstruction of structures and society in the after-earthquake system. It is particularly important to operate three real time systems just after an earthquake occurrence. The first early warning system aims to cope with the phase just before the arrival of strong ground motions. The second system involves the application of structural control technology [Kanda, 1994]. This system plays an important role not only in preventing structural damage but also in maintaining functional losses of important facilities by reducing strong shaking. The third system comprises post-control immediately after the event. It is important to perform emergency response and rapid rescue action to avoid secondary hazards. Damage monitoring, assessment and risk management are important in achieving this. This system has received a lot of attention since the Kobe earthquake associated with rapid development of computer systems such as GIS (Geographical Information System) and telecommunications technologies. Construction of such a real time integrated system centering on structural control will be indispensable to an urban area in the near future.

3. FUTURE STRUCTURAL CONTROL RESEARCH

When the basic concept of an integrated hazard mitigation system is developed, we may describe a new idea, named Urban Control (Fig. 4). The objective of structural control of a building is to reduce strong shaking by utilizing the control theory, while the final goal of urban control is to mitigate earthquake hazards in highly populated regions by applying an expanded concept of control theory. In accordance with the similar flow of structural control, it will be possible to apply the control theory to hazard mitigation of urban areas. That is, in response to the time-dependent variable damage information, the most appropriate emergency action plan is managed by the control theory. The path of structural control research is directed to the next era: a moment to a period, and a point to an area.

4. REFERENCES

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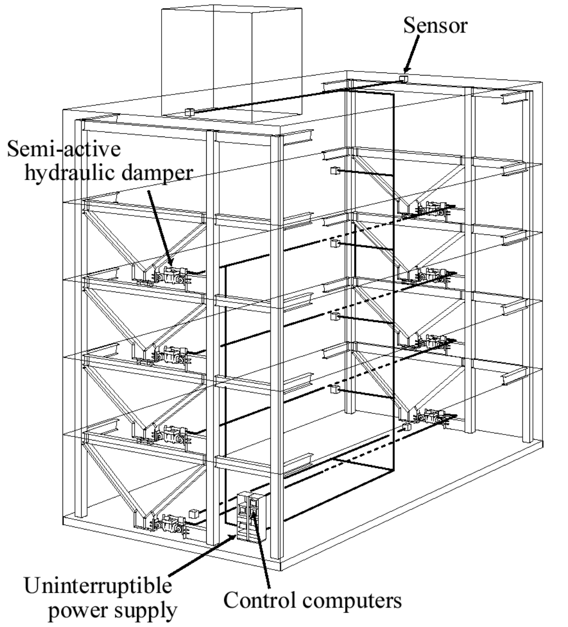
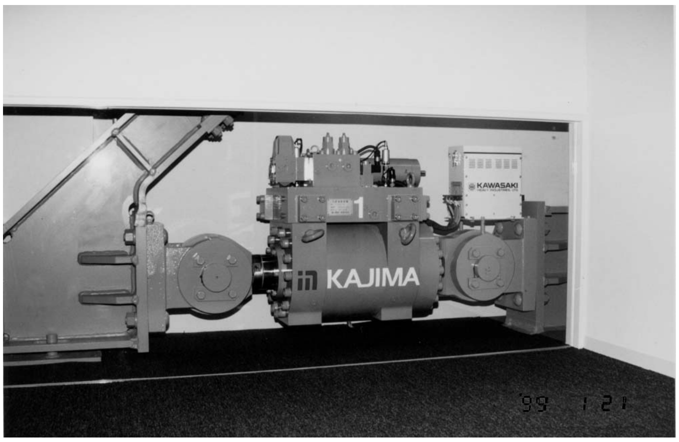
Fig.1 3-Story building with Active Variable Stiffness system

(a) Building outside view



(b) System composition



(c) Semiactive hydraulic damper

Fig.2 Semiactive damper system installed in Kajima Shizuoka BUILDING

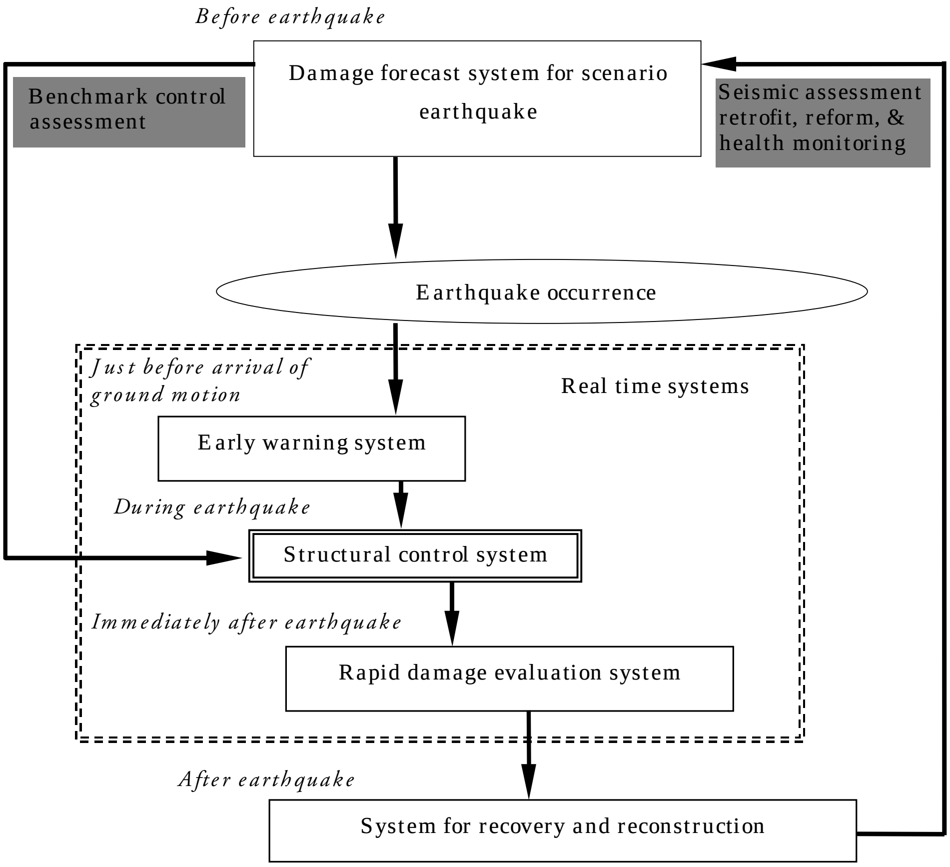


Fig.3 integrated hazard mitigation system

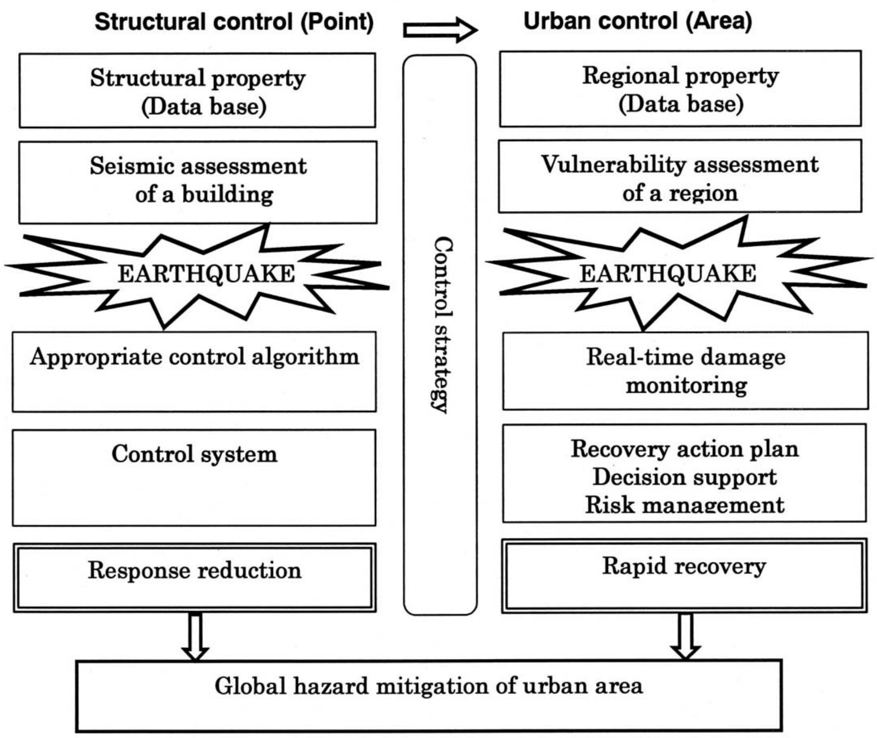


Fig.4 Movement from structural control to urban control