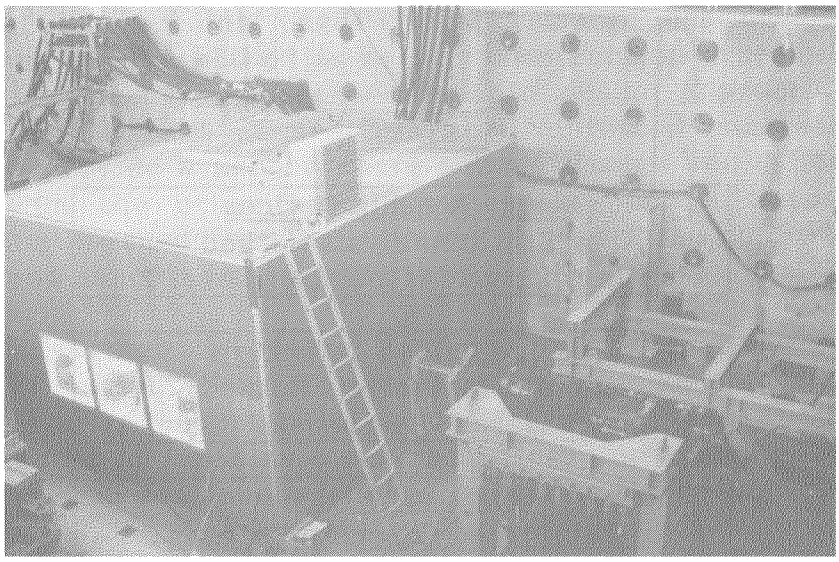

Photo 5 Dynamic Loading Test of Menshin Devices at Public Works Research Institute

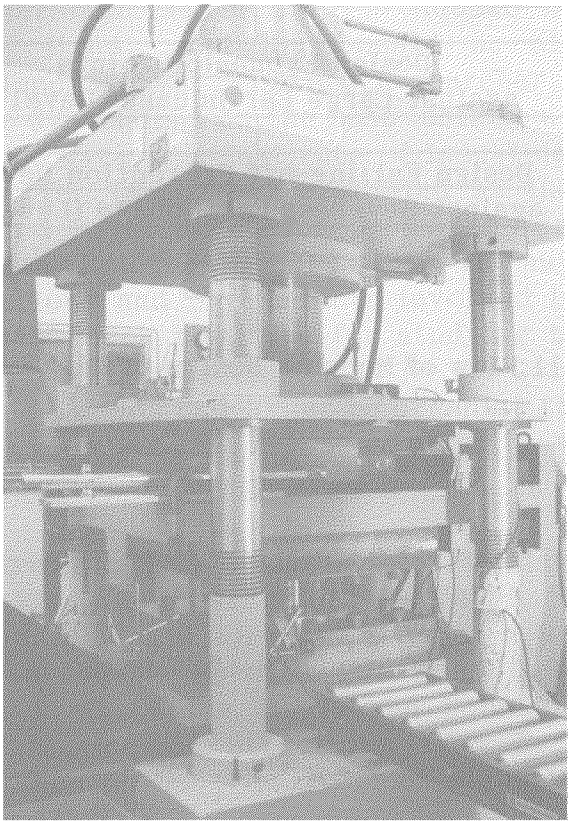

Photo 6 Cyclic Shear Test of Menshin Devices

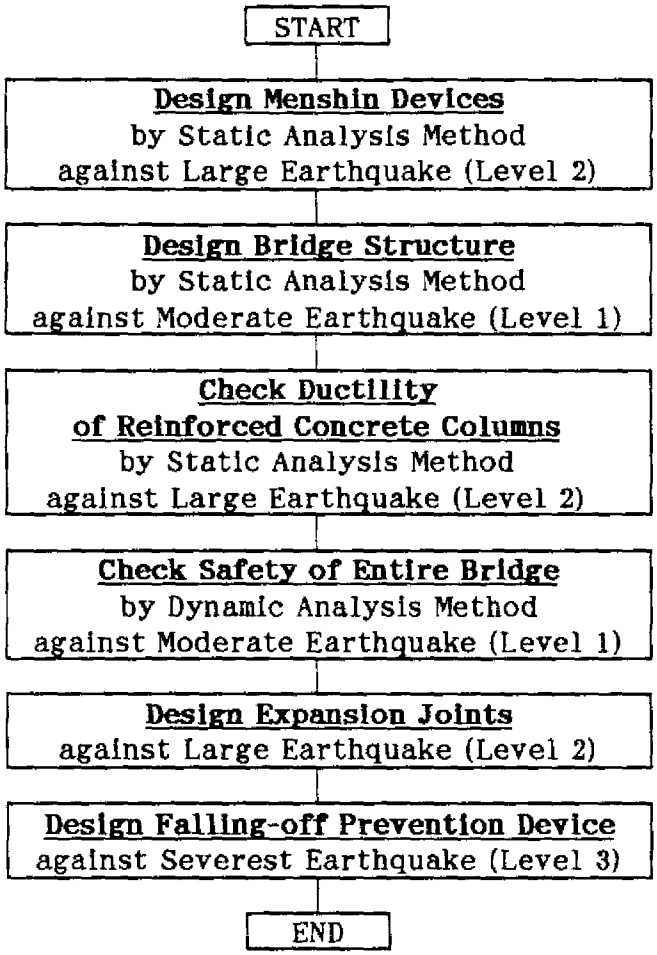

Fig. 11 Flow of Menshin Design of Highway Bridges

CONCLUDING REMARKS

Application of the base isolation to highway bridges in Japan was described in the preceding pages. Seismic damage has been decreased by improving seismic design method as well as construction practices by adopting large lateral force based on the allowable design approach. For further decreasing seismic damage at bearings and reinforced concrete piers, it is appropriate to provide a member where seismic damage would be intentionally concentrated. On the other hand, construction of multi-span continuous bridges is being pursued from the view point of driving comfort, maintenance and release from annoying noise and vibration.

Taking advantage of increasing energy dissipating capability and distribution of lateral force to many piers, the menshin design which is slightly different in concept is being introduced in Japan. The menshin design will be spotlighted in Japan as a new technology for making possible to easily construct multi-span continuous bridges as well as for reducing seismic lateral force.

ACKNOWLEDGEMENTS

For executing investigations presented here, various supports and suggestions have been obtained from many organizations and persons. Special thanks go to Professor I. Buckle, National Center for Earthquake Engineering Research, University of Buffalo, U.S.A., and Mr. Donald K. Kirkcaldie, Works and Development, New Zealand (former Visiting Researcher at PWRI), for their guidance and invaluable discussions on the base isolation. Special appreciation also goes to Professor T. Katayama, Institute of Industrial Science, University of Tokyo, for chairing the Committee formulated at the Technical Research Center for National Land Development for preparing the Guidelines for Base Isolation Design of Highway Bridges (Draft) in 1989. The authors express sincere thanks to all organizations and participants involved in the Joint Research with the Public Works Research Institute for studying the Menshin Design of Highway Bridges , with special appreciation to Mr. Y. Goto, Research Institute of Obayashi Corporation, for his endeavour to organize the research group.

REFERENCES

1)Buckle, I. G. and Mayes, R. L. : Seismic Isolation:History, Application and Performance -A World View, Earthquake Spectra, Vol. 6, No. 2, May 1990

2)McKay, G. R., Chapman, H.E. and Kirkcaldie, D. K. : Seismic Isolation : New Zealand Application, Earthquake Spectra, Vol. 6, No. 2, May 1990

3)Skinner, R.I., Tyler, R. G., Heine, A. J. and Robinson, W. H. : Hysteresis Dampers for the Protection of Structures from Earthquakes, Proc. New Zealand - Japan Workshop on Base Isolation of Highway Bridges, Wellington, New Zealand, December 1987

4)Billings, I. J. and Kirkcaldie, D. K. : Base Isolation of Bridges in New Zealand, Proc. New Zealand - Japan Workshop on Base Isolation of Highway Bridges, Wellington, New Zealand, December 1987

5)Public Works Research Institute : Report of Joint Research between PWRI and 28 Private Firms on Development of Menshin Systems for Highway Bridges, Technical Report of Cooperative Research, No. 44 and No. 60, March 1990 and

March 1991 (in Japanese)
6)Arakawa, T. and Kawashima, K. : Seismicity and Maximum Possible Earthquake around Japan for Application to Seismic Risk Analysis, Technical Note No. 2098, Public Works Research Institute, March 1984 (in Japanese)
7)Japan Road Association : Guide Specifications for Earthquake Hazard Mitigation for Transportation Facilities - Post-Earthquake Countermeasures-, February 1987 (in Japanese)
8)Kawashima, K. : Seismic Design, Seismic Strengthening and Repair of Highway Bridges in Japan, Proc. U.S.-Japan Workshop on Seismic Retrofit of Bridges, Public Works Research Institute, Tsukuba, Japan, 1990
9)Japan Road Association : Guide Specifications for Earthquake Hazard Mitigation for Transportation Facilities - Pre-Earthquake Countermeasures-, February 1987 (in Japanese)
10)Iwasaki, T., Penzien, J. and Clough, R.W. : Literature Survey - Seismic Effects on Highway Bridges, Report No. EERC 71-11, Earthquake Engineering Research Center, University of California, Berkeley, 1972
11)Public Works Research Institute : Report on Niigata Earthquake, Vol.125, June 1965 (in Japanese)
12)Japan Road Associations : Design Specifications for Highway Bridges - Part V Seismic Design -, February 1990 (in Japanese)
13)Iwasaki, T., Kawashima, K. and Hasegawa, K. : New Seismic Design Specifications of Highway Bridges in Japan, 22nd Joint Meeting, U.S.-Japan Panel on Wind and Seismic Effects, UJNR, Gaithersburg, U.S.A., May 1990
14)For example, Katayama, T., Kawashima, K., and Murakami, Y. : Current Design Considerations for Reducing Seismic Lateral Force of Highway Bridges in Japan, New Zealand - Japan Workshop on Base Isolation of Highway Bridges, Wellington, New Zealand, December, 1987 (Procs. are available from Technical Research Center for National Land Development, Tokyo, Japan)
15)Yahagi, K. and Mizumoto, Y. : Past and Present of Seismic Design, Bridge and Foundation Engineering, Vol. 13, No. 10, 1979(in Japanese)
16)Matsumura, S., Fukuoka, S., Mizumoto, Y. and Nakata, T. : Seismic Design of Multi-span Continuous Bridge with Damper, Bridge and Foundaiton Engineering, Vol. 16, No. 5, 1982 (in Japanese)
17)Iseki, J. : Viscous Damper, Society of PC Technology, Vol. 21, No. 4, August 1979 (in Japanese)
18)Okamoto, S. and Uemae, Y. : Aseismic Bridge Structure by Elastic Supports Using Tie Members (SU Damper Method), Proc. Symposium on New Ideas in Structural Design, Japan Society of Civil Engineers and Architectural Institute of Japan, 1963 (in Japanese)
19)Kitazawa, M., Ishizaki, H., Emi, S. and Nishimori, K. : Characteristics of Earthquake Responses and Design of Aseismic Design on the Long-period Cable-stayed Bridge (Higashi-Kobe Bridge) with All Movable Shoes in Longitudinal Direction, Procs. Japan Society of Civil Engineers, No. 422/I-14, October 1990 (in Japanese)
20)Maeda, K. and Eya, S. : Adoption and Dynamic Characteristic of Short Link Bearing in Yokohama Bay Bridge, Bridge and Foundation Engineering, Vol.24, No.9, September 1990 (in Japanese)
21)Kanemitsu, H. and Higuchi, K. : Displacement Control of Bridges with Suspended Girder, Technical Report of the Honshu-Shikoku Bridge Authority, 1981 (in Japanese)
22)Kato, N., Iioka, Y. and Kawahito, T. : Design of Meiko-nishi Bridge, Bridge and Foundation Engineering, 1983 (in Japanese)
23)Fukuoka, S. : Design of Multi-span Continuous Highway Bridges with Use of

Shear Viscous Damper, Bridge Engineering, 1980 (in Japanese)
24)Sakairi, Tominaga, Kiyota and Sasaki : Vibration Characteristics of 5-span Continuous Steel Box Girder Bridge Supported by Rubber Bearings, 44th Annual Meeting, Japan Society of Civil Engineering, September 1989 (in Japanese)
25)Public Works Research Institute : Report on the Disaster Caused by the Miyagi-ken-oki Earthquake of 1978, Vol. 159, March 1983 (in Japanese)
26)Personal Discussion with Mr. James Gate, California Department of Transportation, and Mr. Shoichi Saeki, Honshu Shikoku Bridge Authority
27)Williams, D. and Godden, W. G. : Experimental Model Studies on the Seismic Response of High Curved Overcrossings, Report No. EERC 76-18, Earthquake Engineering Research Center University of California, Berkeley, 197
28)Kawashima, K. and Penzien, J. : Correlative Investigation on Theoretical and Experimental Dynamic Behavior of A Model Bridge Structure, Report No. EERC 76-26, Earthquake Engineering Research Center, University of California, Berkeley, 1976
29)Kawashima, K. : An Analytical Model of Contact and Impact in Dynamic Response Analysis, Proc. Japan Society of Civil Engineers, Vol. 308, April 1981
30)Technology Research Center for National Land Development : Guidelines for Design of Base-isolated Highway Bridges, Final Report of Base Isolation to Seismic Design of Highway Bridges (Chairperson : Professor T. Katayama), March, 1989 (in Japanese)
31)Kakizaki, H. and Ito, T. : Menshin Design of Nagaki-gawa Bridge, Bridge and Foundation Engineering, Vol. 90-9, September 1990 (in Japanese)
32)Matsuo, Y., Ooishi, A., Hara, K. and Yamashita, M. : Design and Construction of Miyagawa Bridge, Bridge and Foundation Engineering, Vol. 91-2, February 1991 (in Japanese)
33)Ikeda, T., Oozeki, K., Kumakura K. and Abe, N. : Design of Karasuyama No. 1 Bridge (Base Isolated Bridge), Bridge and Foundation Engineering, Vol. 25, No. 6, June 1991(in Japanese)
34)Kawashima, K., Hasegawa, K., Unjoh, S., Nagashima, H., and Shimizu, H. : Current Research Efforts in Japan for Passive and Active Control of Highway Bridges against Earthquake, 23rd Joint Meeting, U.S.-Japan Panel on Wind and Seismic Effects, U.J.N.R., Public Works Research Institute, Tsukuba, Japan, May 1991