A PERSPECTIVE OF MENSHIN DESIGN FOR HIGHWAY BRIDGES IN JAPAN

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SUMMARY

Presented are current technical developments for the base isolation to ordinary size of highway bridges with span length from 10 m to 50 m in Japan. Seismic environment, history of seismic damage and formulation of seismic design codes are firstly described with emphasis on motivation for introducing the base isolation. Because elongation of natural period of bridges is quite difficult to be adopted due to various restrictions associated with deck displacement, a "Menshin Design" which aims even distribution of lateral force to each substructure as well as increase of energy dissipating capability is becoming to be incorporated. Existing and current efforts for developing the Menshin Design including pilot construction and a joint arch program of the Menshin Design is presented.

INTRODUCTION

Highways in Japan consist of Expressways (3,721 km), National Highways (46,661 km), Prefectural Roads (128,202 km) and Municipal Roads (925,138 km). Along the highways and roads, excluding the Municipal Roads, there are about 60,000 bridges with span length of 15 m or longer. Although the number of bridges constructed per year depends on the year and span length, it is about 6,000 for concrete bridges and 2,000 for steel bridges with the length of 15 m or longer.

Base isolation has been highlighted in Japan as a new technology to reduce seismic response of structures, and more than 30 base-isolated buildings have been constructed. The principles of base isolation is to elongation the natural period of a structure and enhance the energy dissipating capability with a base isolation device, which consist of an isolator and an energy dissipator. Although the base isolation has been applied to highway bridges in New Zealand and U.S.A.(Refs. 1 - 4), seismicity is higher and ground condition is softer in Japan, so that a specific research and development be inevitable for applying the base isolation to highway bridges in Japan.

This paper describes the current efforts for incorporating the base isolation to seismic design of highway bridges. Because design consideration is different with large bridges such as cable-stayed bridges, description is concentrated here to ordinary size of highway bridges with span length of 10 to 50 m. Overcrossing and viaduct in city area is also included here as "bridge". Seismic design philosophy of those highway bridges including the the history of bridge damage in the past and past revision of seismic design codes is presented with emphasis on the motivation for incorporating the base isolation. Because elongation of natural period is difficult to be adopted and distribution of lateral force to substructures is now becoming considerably important, a slightly different concept with the base isolation is being introduced by taking advantages of energy dissipation and distribution of lateral force. It is referred as "Menshin Design". Outline of the existing and on-going researches including a joint program between the Public Works Research Institute and 28 private firms entitled "Development of Menshin Design of Highway Bridges" (Ref. 5) are also presented.

CURRENT SEISMIC DESIGN AND PHILOSOPHY OF HIGHWAY BRIDGES

<u>**History of Earthquake Damages**</u> Located along the Pacific Seismic Belt, Japan is one of the most seismically disastrous countries in the world and has often suffered significant damage from large earthquakes. **Fig. 1** shows the largest magnitude of the earthquakes which occurred in the past (Ref. 6). It is recognized that the earthquakes with magnitude over 8 occurred with rather short recurrent period in and around Japan in the past. It should be noted that seismicity is especially high along the Pacific coast where large cities in population and industrial products such as Tokyo, Osaka and Nagoya are located.

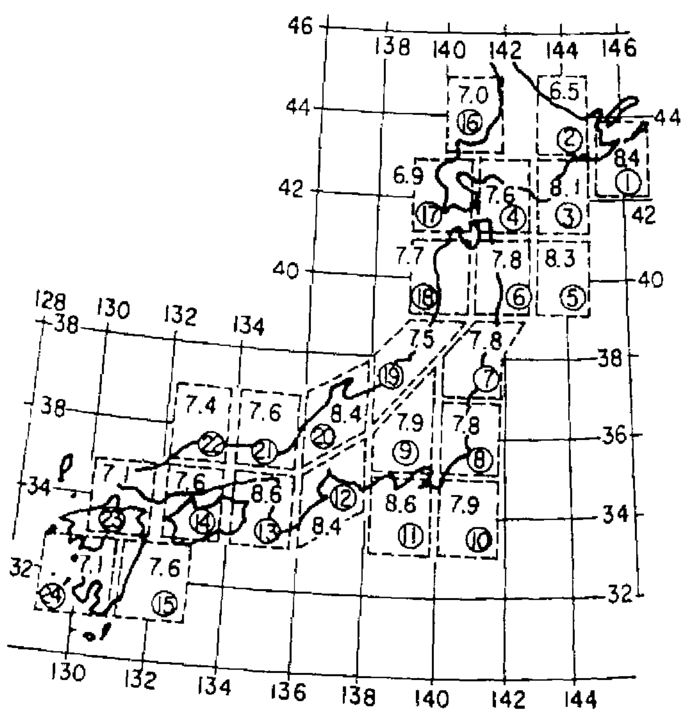

Fig. 1 Largest Earthquake Magnitude Which Occurred in the Past

Table 1 shows the highway bridges which suffered damages in the past earthquakes since the Kanto Earthquake of 1923 (Ref. 7). It should be noted that although there were many bridges which suffered damages due to earthquakes, number of bridges which fell down was only 15. It is important to note that damage types have been varying as shown in **Table 2** in accordance with the progress of the seismic design method and improvement of construction practice. Seismic damage since the 1923 Kanto Earthquake may be classified into three stages from their significance (Refs. 8, 9).

Table 1 Number of Highway Bridges Which Suffered Damage in the Past Earthquakes after 1923 Kanto Earthquake

DATE	EARTHQUAKE	MAGNITUDE	NUMBER OF BRIDGES DAMAGED	NUMBER OF BRIDGES WHICH FELL DOWN
1923. 9. 1	KANTO	7.9	1,785	6
1946.12.21	NANKAI	8.1	346	1
1948. 6.28	FUKUI	7.3	243	4
1949.12.26	IMAICHI	6.4	1	0
1952. 3. 4	TOKACHI-OKI	8.1	128	0
1962. 4.30	MIYAGI-KEN-HOKUBU	6.5	187	0
1964. 6.16	NIIGATA	7.5	98	3
1968. 2.21	EBINO	6.1	10	0
1968. 5.16	TOKACHI-OKI	7.9	101	0
1978. 1.14	IZU-OHSHIMA	7.0	7	0
1978. 6.12	MIYAGI-KEN-OKI	7.4	95	1
1982. 3.21	URAKAWA-OKI	7.1	5	0
1983. 5.26	NIHON-KAI-CHUBU	7.7	176	0
1984. 9.14	NAGANO-KEN-SEIBU	6.8	14	0
TOTAL			3,191	15

Table 2 Change of Seismic Damage Mode

Year	Major Earthquakes	Change of Major Seismic Damage	Seismic Design Method	Seismic Inspection and Strengthening
1920	1923 Kanto Earthquake (M7.9)	Failure of Superstructure due to Tilting/Movement of Foundation	1926 Initiation of Seismic Design (Details of Road Structures)	
1930				
1940	1946 Nankai Earthquake (M8.1) 1948 Fukui Earthquake (M7.3)	Failure of Concrete around Fixed Bearing Damage due to Liquefaction	1939 Introduction of Standard Seismic Coefficient (Design Specifications of Steel Highway Bridges)	
1950	1952 Tokachi-oki Earthquake (M8.1)	Failure of RC Piers, and Bearing	1956 Seismic Coefficient depending on Zone and Ground Condition (Design Specifications of Steel Highway Bridges)	
1960	1964 Niigata Earthquake (M7.5)			
1970	1978 Miyagi-ken-oki Earthquake (M7.4)		1971 • Seismic Coefficient depending on Zone, Ground Conditions, Importance and Structural Response • Introduction of Evaluation Method for Liquefaction (Specifications for Seismic Design)	1971 Seismic Inspection 1976 Seismic Inspection 1979 Seismic Inspection
1980	1982 Urakawa-oki Earthquake (M7.1) 1983 Nihon-kai-chubu Earthquake (M7.7)		1980 • Part V Seismic Design, Specifications for Design of Highway Bridges • Introduction of New Evaluation Method for Liquefactions	1986 Seismic Inspection
1990			1990 Part V Seismic Design, Specifications for Design of Highway Bridges	

1) Stage 1 - Damage due to Inadequate Strength of Foundations

After experiencing the destructive damage of the 1923 Kanto Earthquake, the first requirements for seismic design of highway bridges were included in the "Details of Road Structures (Draft)" issued in 1926. No seismic effects were considered for design of highway bridges prior to the Kanto Earthquake. Even after the first stipulations, seismic design was not adequate because the stipulations only described design force levels without providing detailed design method and design details. Therefore, seismic safety of bridges was short until the 1950's when seismic design for foundations and substructures came to be widely improved.

In those days when seismic effects were either disregarded or poorly considered, seismic damage was characterized by failure of foundations and substructures as shown in **Photo 1**. In most cases, foundations were tilted, moved or even overturned due to insufficient strength of the foundations and the surrounding subsoils, which led to falling-off of the superstructures (Ref. 10).

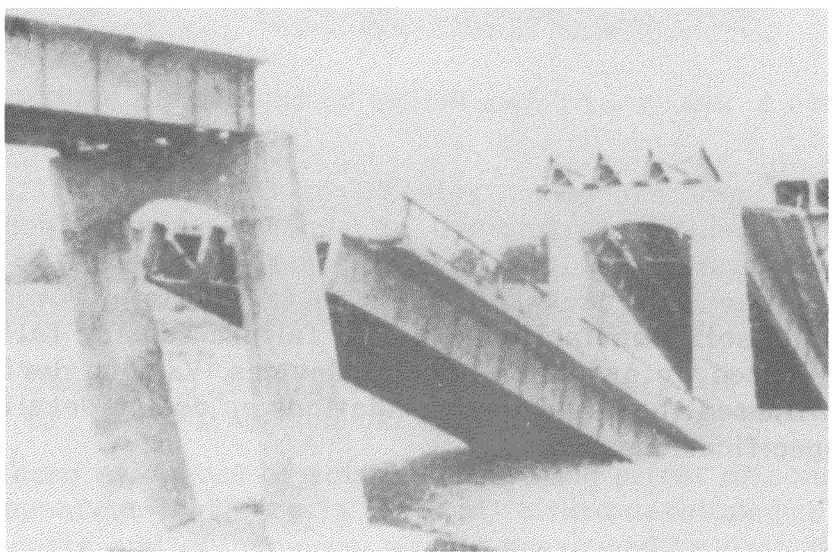

Photo 1 Damage of Nakazuno Bridge by the Fukui Earthquake of 1948

2) Stage 2 - Damage due to Soil Liquefaction

Although the damage due to inadequate strength of foundations became less frequent by the improvement of seismic design and construction methods for substructures, the next stage of earthquake damage encountered was soil failure in conjunction with liquefaction prominently observed during the 1964 Niigata earthquake. **Photo 2.** shows the falling-off of the decks of the Showa bridge in the earthquake. Extensive soil movement associated with liquefaction produced large lateral movements of the bent pile foundations, which caused the dropping-off of the deck (Ref. 11). Responding to the damage, the first stipulations for assessing vulnerability of liquefaction were introduced in the "Design Specifications for Seismic Design of Highway Bridges" in 1971 through extensive studies initiated after the earthquake.

Photo 2 Damage of Showa Bridge by the Niigata Earthquake of 1964

The other important lesson gained from the Niigata earthquake was that devices for preventing falling-off of superstructures from the crest of columns are unavoidable. It was considered that even if large relative movements between the deck and the substructures occurred due to soil failures such as soil liquefaction, critical failure causing falling-off of deck could be prevented by providing special devices. Various devices as shown in **Fig. 2** were proposed then, and recommendations on design details were included in the 1971 Specifications.

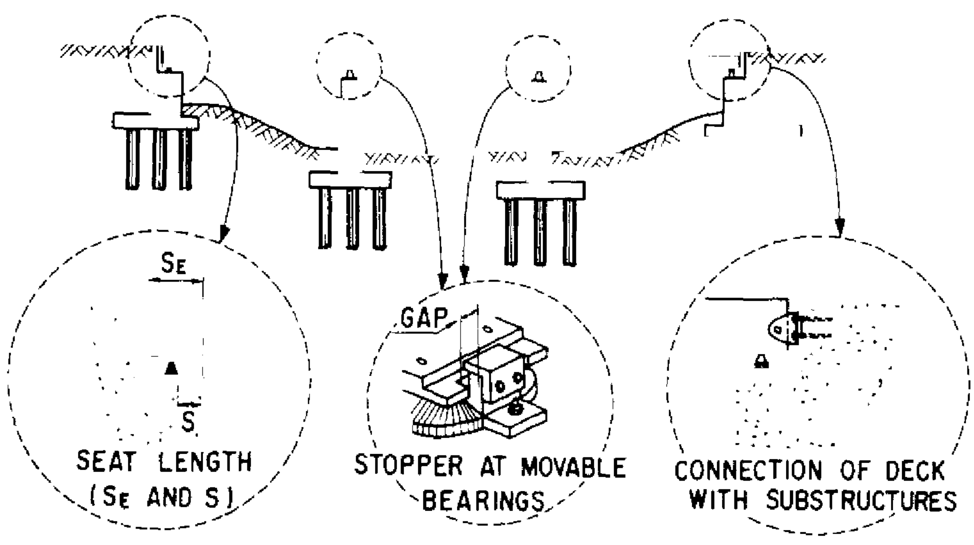

Fig.2 Devices for Preventing Superstructure from Falling