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RECOMMENDATIONS FOR STRENGTHENING BRIDGES ON HIGHWAYS AND RAILROADS DAMAGED BY THE JAN. 17, 1995 GREAT HANSHIN EARTHQUAKE

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1. INTRODUCTION

The **Great Hanshin Earthquake of Jan. 17,1995** severed the road networks in Kyogo Prefecture, so they have fallen into the situation of not fulfill their function anymore. The earthquake was magnitude 7, the highest in the Japanese scale. Peak horizontal accelerations were as higher as 0.8g in some places such as in Kobe Meteorological Station while accelerations in the vertical direction were about 0.4g in several places such as Kobe University and JR Takarazuka station among others.

2. PRINCIPAL DAMAGE TO BRIDGES ON THE HANSHIN EXPRESSWAY, MEISHIN HIGHWAY, CHUGOKU HIGHWAY, ROUTE 2 - KOBE LINE, NATIONAL,PREFECTURAL AND CITY ROADS

Severe damage did occur along the mentioned Highways and Expressways such as those in Nishinomiya, Amagasaki,, Ashiya, Itami, Ikeda, Kawanishi, Takarazuka, Toyonaka and Kobe cities,etc.

The majority of highway bridges in the quake-affected are of common types such as:

- Simple steel plate or box girder or multiple spans continuous steel box girder.
- RC single or multiple spans (orthogonal or skewed) bridges.
- Gerber, Multiple spans composite plate girder and simple supported PC or Steel box girder.

The aforementioned bridges are supported by :

- T-type RC bents (with circular or rectangular columns).
- Framed bents (RC or steel) with circular or rectangular columns.
- RC piers of several cross sections such as : wall type , ovaled and elliptical.
- Finally, T-type abutments and gravity abutments.
- The foundation in the majority of bridges are on both cast-in-place piles and spread.

The damage encountered on almost all inspected bridges are:

- Lateral or longitudinal displacement of girders, buckling of steel girders.
- Fall of bridge girders due to collapse of piers or bearing supports.
- Buckling at the bottom of steel columns, separation between bridge and its approach. Settlement of columns. Fig. 1 shows an overview of damage to bridges on Highways in the ravaged area.

3. PRINCIPAL DAMAGE TO BRIDGES ON RAILROADS : THE JR SHINKANSEN LINE, JR ORDINARY LINES, HANSHIN MAIN LINE, HANKYU LINE, KOBE NEW TRANSIT PORT ISLAND AND ROKKO ISLAND LINES

Remarkable damage occurred at some overhead bridges on routes of the bullet-train (shinkansen), such bridge structures were seismically designed by taking into account the effects of The Great Kanto Earthquake of 1923. It put the Japanese current standards for bridge design in the imperious necessity to be re-examined. The Kobe-New-Transit Port Island Line was built in 1977-1980 and the Rokko Island Line in 1972-1990. The bridges in the quake-affected area along the Shinkansen line (Bullet train) are typically RC continuous rigid frames with RC bents or T-type bents with rectangular or circular columns.

The quake-damage on the JR Shinkansen line bridges are reported as following:

- Displacement, collapse or fall of girders caused by severe shear failure of bents and bearing supports.
- Severe damage in the middle and atop of RC columns.

The bridge structures on railways are of several types with predominance of steel box girders on steel framed bents or single steel columns of circular or rectangular cross section.

The damage to railroad bridges can be described as follows:

- Slip down of steel girder caused by breakage or buckling of connection devices at bearing supports, sinkage, rotation or fall of girders, tilting or collapse of retention walls.
- Concrete spalling due to shear and flexural failure on columns, break of the alignement of rail-tracks caused by the fall of surrounding structures or collapse of slopes.

4. CONCLUSIONS

This report is made on basis of a site survey on almost all bridge structures located in the quake-affected area. By the inspection of damaged or collapsed bridges is clear that **a large number of of them were designed long time ago**. Another important factor to be considered is that **almost all of collapsed structures had not been retrofitted** to increase their resistant capacity against large earthquakes. Finally, **this earthquake showed more than ever, the effect of vertical acceleration** on the failure mechanism of collapsed structures.

The lessons from this earthquake prompt a necessary revision of the current standards for bridges design. By this way, available **guidelines for bridge retrofitting should be up-graded and put on practice in the nationwide.**

5. RECOMMENDATIONS

- The **lack of enough adhesion, bearing interaction and friction at bond between concrete and steel reinforcement (anchorage)** during the strong shaking are founded to be the principal causes that initiated the failure and collapse of many bridge piers. It leads to recommend that length of anchorage, quality of concrete as well as quality in the reinforcement detail construction must be improved.
- The **shear reinforcement and anchorage of steel bars was deficient** in almost all collapsed bridges. It leads to recommend that space in lateral confinement should be shortened as well as welded in the lap-splices zone. Diameter of bars for lateral confinement should be also increased specially in the zones with could develop plastic hinges.
- Both, **continuous and simply supported girders of many spans (RC, PC or steel) were severely damaged**. By the other hand, Most of the damaged structures were supported on older RC piles, pedestal piles and caissons. However the damage to foundation structures was relative small. Retrofitting of columns with steel jackets, detailed inspection on footings and strengthening of piles should be carry out. Piles groups can be framed in order to increase their resistance capacity.
- In order to investigate the causes of damage it **is necessary to elucidate the collapse mechanism associated with the type of structure, seismological and geological conditions of the site as well as the the damage distribution in the overall ravaged area. So Available Non-Linear FEM computer programs should be used in order to modelate the ground conditions as well as concrete behaviour under cyclic reversals.**

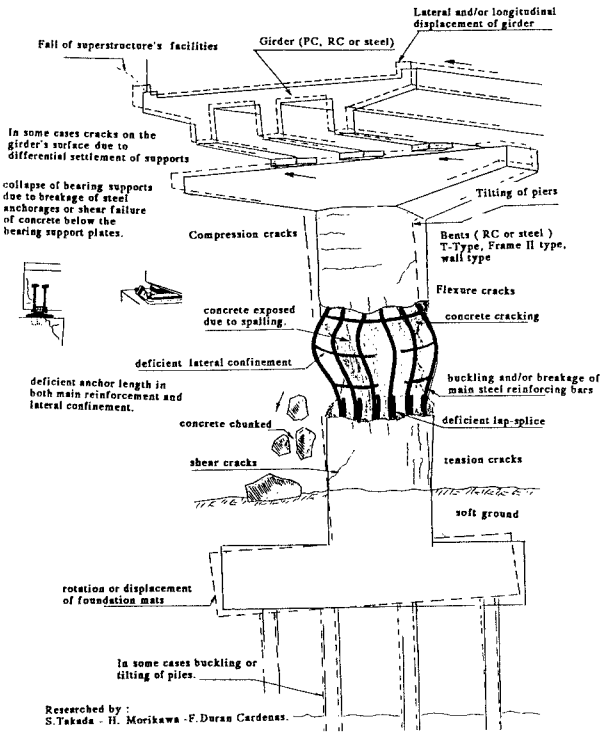

Fig. 1 Bridge damage on Highways and Railways caused by the Great Hanshin Earthquake of Jan. 17,1995