A New Type Shock Absorber and its Effects on the Response of the Bridge to the Earthquake

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1. Introduction

A new type of shock absorber called "stopper," has been used with the movable shoe at the support of the prestressed concrete railway bridges in Japan since 1969.

The main effects of stopper are 1) to distribute the longitudinal horizontal force acting on a girder during an earthquake even to the movable supports in case of a continuous girder, 2) to reduce the maximum values of the response by energy absorption, 3) to decrease the relative displacements among the tops of piers during an earthquake.

2. A new type shock absorber; "stopper"

The constitution of the stopper is shown in Fig. 1. A steel rod, fixed at the lower surface of the concrete girder, fits in a box at the top of the substructure. The box is filled by a viscous material, which flows without remarkable resistance against the displacement of the stopper due to the temperature change or shrinkage of a concrete girder. However, the stopper acts as a damper against dynamic load such as earthquake force because it posseses the characteristics of viscous damping.

As seen in the Fig. 1, a glide plate is pushed to the upper plate by a spring at the entrance of the gap at the stopper. This prevents overflow of the viscous material. The stopper is designed to resist a horizontal load, but it dose not carry a vertical load, which is transmitted by shoe support.

The viscous material consists of a mixture of asphalt and polyma solution, and have a viscosity of 4.0×10^3 poise at 30°C. At a lower temperature the viscosity rises remarkable, for instance 1.8×10^4 poise at 0°C, 9.0×10^4 poise at -20°C. The material still remains to be viscous even under a temperature of -20°C.

The tests of the stopper was carried out, changing the velocity and the dimension of d in wide range. The main temperature during the test was 25°C.

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Resistance-Velocity curves of the test are drawn with full lines in Fig. 2 and proved that the resistance of this stopper was approximately proportional to $V^{0.6}$ and $d^{-1.6}$ respectively. In dynamic equation of motion, this resistance corresponds to C in the viscous damping term Cx and the similar bi-linear lines with dotted line in Fig. 2 are applicable.

3. The effects of the stopper on the response of the bridge to the earthquake

To know effects of the stopper, dynamical analysis of several cases with and without stopper was carried out. The analytical model was made by replacing the structure to mass-spring system.

Bridge with simply supported girder is shown in Fig. 3. Being neglected the frictional resistance of the movable support, two independent vibration systems like Fig. 4 (a) can be gotten as the vibration model. El Centro Earthquake wave (1940, NS) of its maximum acceleration 300gal was applied to the base rock. The subsoil layers, then, was replaced by the springs of sway and rotation. The results of analysis are the following. The movements at the tops of the pier P_1 and P_2 are quite different each other as shown in Fig. 5 (a). In extreme case, the directions of the displacements of P_1 and P_2 reverse each other. In such a case, it could happen that ajoining girders which are fixed at the top of each substructure hit each other at the end of the girders and it causes a failure of the shoes. Also the possibility of falling down of the girders at their movable end is not negligible.

If we put a stopper at the movable support, the relative displacement between the tops of P_1 and P_2 becomes smaller than that of the model without stopper as seen in Fig. 5 (a) and 5 (b). We can recognize that the displacement in Fig. 5 (b) is smaller than that in Fig. 5 (a) in average due to the damping effect of the stopper.

The results of the analysis in case of a three spans continuous girder show that the distribuiton of the horizontal reaction in longitudinal direction is proportional to the rigidity of the substructure like in the case of pin connection between the girders and substructures, and the maximum reaction at each support (Case 2 in the Table 1) is smaller than in the case of pin connection (Case 1 in the Table 1) due to the damping effect of the stopper.

	P_1	P_2	P_3	P_4
CASE-1	1120	1495	1495	1120
CASE-2	950	1241	1262	950

Table 1 Maximum Horizontal Reaction (ton) at each Stopper

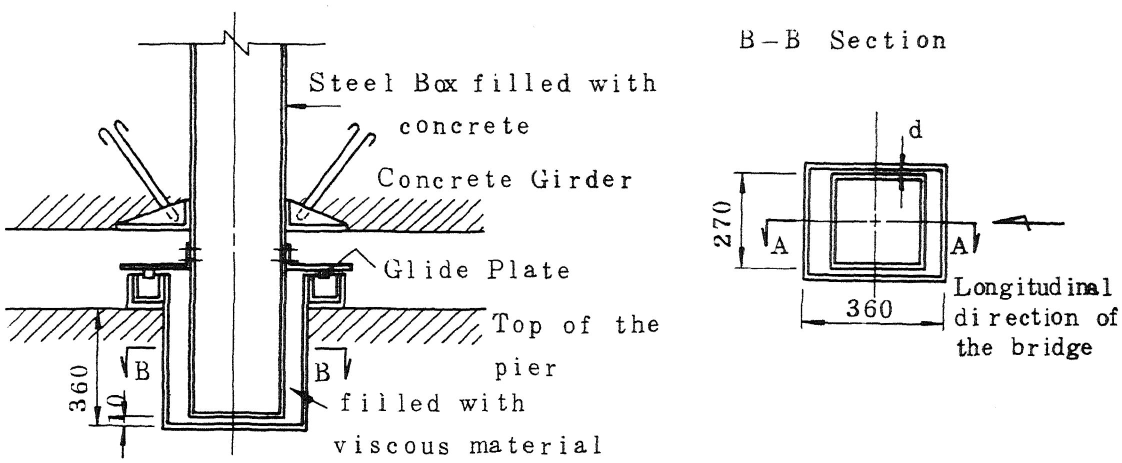

Fig 1 Constitution of Stopper

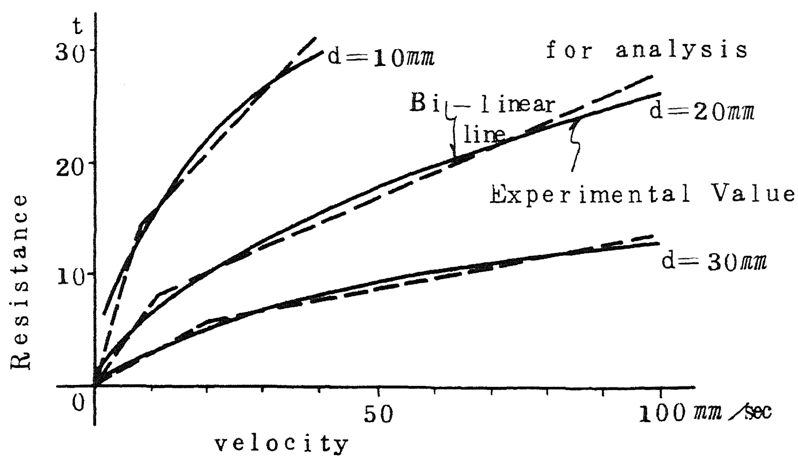

Fig 2 Resistance of Stopper to Velocity

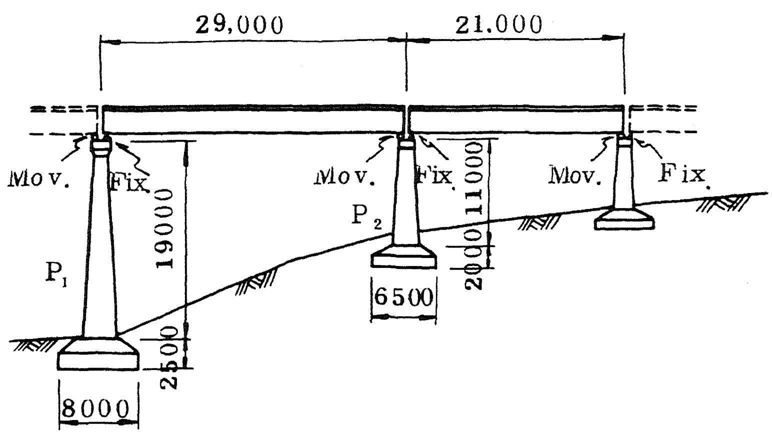

Fig 3 Simply Supported Bridge Model

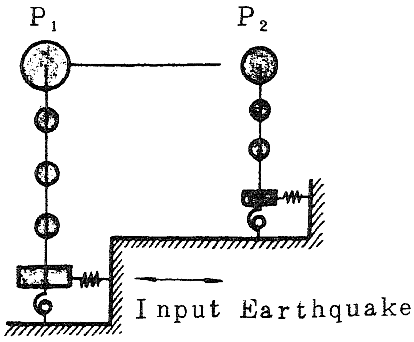

Fig 4(a) Vibration Model of Bridge without stopper

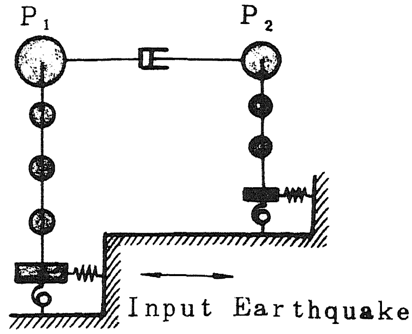

Fig4(b) Vibration Model of Bridge with stopper

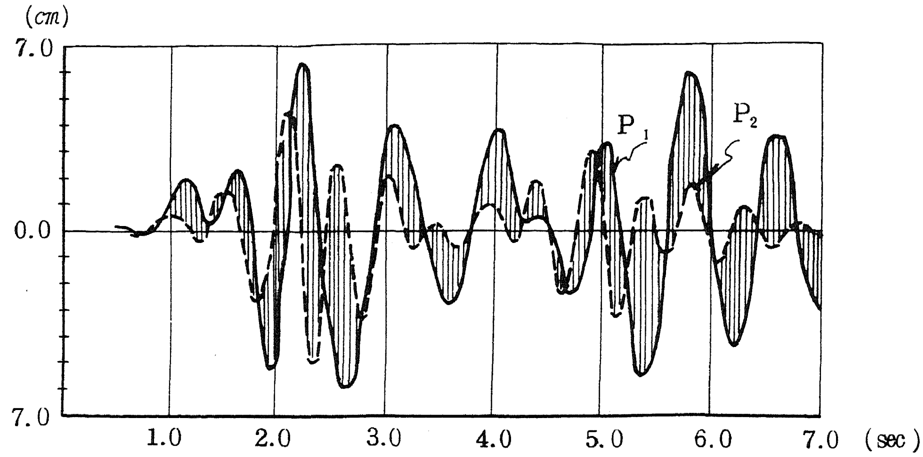

Fig5(a) Displacement Time History Curves at the Top of Piers of the Model without Stopper.

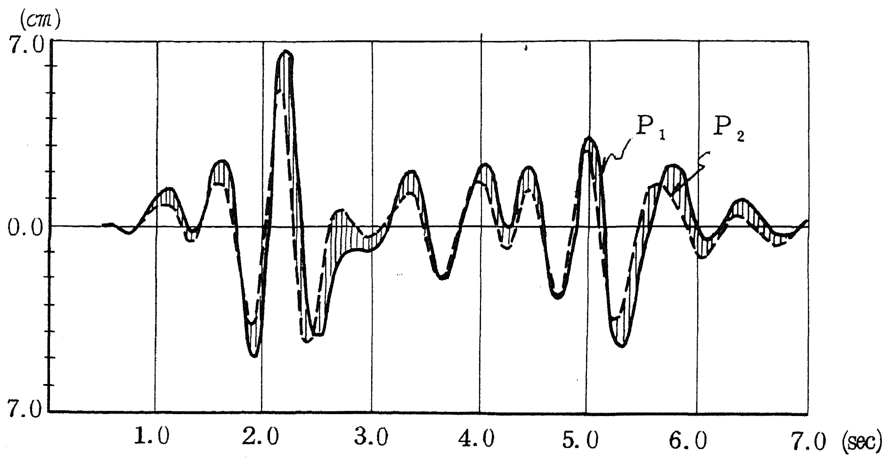

Fig 5(b) Displacement Time History Curves at the Top of Piers of the Model with Stopper.